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International Laser Safety Standardisation

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International Laser Safety Standardisation
From the European Perspective With an Emphasis on Materials Processing

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List of abbreviations

Organisations

ACGIH	*American Conference of Governmental Industrial Hygienists*
AFNOR	*Association Francaise de Normalisation* French Standards Institution
ANSI	*American National Standards Institute*
BSI	*British Standards Institution*
CDRH	*Center for Devices and Radioligal Health (USA state agency)*
CEC	*Commission of the European Countries*
CEN	*Comité Européen de Normalisation* European Commitee for Standards
CENELEC	*Comité Européen de Normalisation Electrotechnique* European commitee for electrotechnical standardization
CIE	*Commission Internationale de l'Éclairage* International Commission on Illumination
ETSI	*European Telecommunication Standards Institute*
FDA	*Food and Drug Administration (head organisation of the CDRH)*
ICNIRP	*International Commission on Non-Ionizing Radiation Protection*
IEC	*International Electrotechnical Commission*
ISO	*Internationl Standards Organisation*

Commonly used abbreviations

A1	Amendment 1, etc. (1st update)
BT	*Bureau Technique* (Technical Bureau) (CEN, ISO)
CC	Compilation of Comments
CD	Committee Draft
CDC	Committee Draft for Comment (IEC terminology, now superseded by „CD“)
CDV	Committee Draft for Voting (IEC terminolgy)
CNC	Short for CENELEC
Cor.	Corrigendum (also sometimes numbered Cor. 1, etc.)
DIN	*Deutsches Institut für Normung* German Standards Institution
DIS	Draft International Standard (ISO terminology)
doa	latest date of announcement (at national level)
dop	latest date of publication (national implementation)
dor	date of ratification
dow	latest date of withdrawal (of conflicting national standards)
EC	European Community
EEC	European Economic Community

EN	European Norm
eqv	equivalent technical content, but not completely identical (see idt)
ETS	European Telecommunication Standard
FDIS	Final Draft International Standards
idt	identical (a CEN/CLC standard in relation to an intern. standard, see also equ)
NC	National Committee (member organisations of the IEC)
NP	New Work Item Proposal
O	Observing (National) Member in a TC
P	Participating (National) Member in a TC
prEN	Draft EN (pr...project)
PWI	Preliminary Work Item
SC	Sub-Committee
NP	New Work Item Proposal (old version: NWIP)
RVD	Result of Voting
TC	Technical Committee
TR	Technical Report
WG	Working Group

1 Introduction

1.1 Scope

This report reviews international standards relevant to the safety of laser products and laser installations, with an emphasis on the safety of laser materials processing from the European perspective. In the first paragraphs an overview of the international standards organisations, their relative roles and ways of developing new standards is given. In the second part of the report, work currently underway in the respective standards committees is summarised and specific standards dealing with different aspects of laser safety are discussed. An appendix contains a list of standards organised in standards organisations IEC, ISO and EN).

1.2 Basics

Standards are a means of defining the technical specifications for a group of products to either ensure compatibility with other products or to ensure a minimum level of safety which is common to all the products which comply to the standard. Thereby standards can be related to technical specifications such as the size of paper and the shape of screws or they can be safety related and deal for instance with the minimum value of insulation, with design requirements such as interlocks or with safety classification and warning labeling.

Also the level of internationality of standards can vary from world-wide international standards, regional standards such as European Standards to national standards which are published by the national standards organisation and are only applicable in one country.

Standards are developed by committees which consist of experts in the field, however, in order to insure the acceptability of the standard, for every level of internationality interested parties must have the opportunity to participate in the work and to influence its outcome.

In an ever intensifying global market and especially in a single European market, international standards play a vital role to insure free trade - for a product which is tested in one country and complies to the standards which are applicable in this country, international standardisation is the basis for the acceptance of this product in all other countries which have installed identical standards.

Standards are not laws or binding regulations as such, however they can be „cited" in laws, governmental or European regulations to specify technical details, thereby becoming legally binding. This is especially attractive in fields where there is a rapid progress, as international standards are usually based on a wider expert knowledge with consensus of different interest groups and also can be more efficiently adopted to the latest technical developments than legislation.

To summarise, international standards are developed according to the following principles:

- **Consensus**

The views of all interested parties are taken into account: manufacturers, vendors and users, consumer groups, testing laboratories, governments, engineering professions and research organisations.

- **Industry-wide**

Global sulutions to satisfy industries and customers worldwide

- **Voluntary**

International standardisation is market-driven and therefore based on voluntary involvement of all interests in the market-place. It should be noted, however, that this principle is only applicable to world-wide international standards, not to standards published by the European standards organisation which *have* to be adopted by member nations.

2 International Standardisation

The inter-relation of the different standards organisations is schematically depicted below in Figure 1. In the field of standardisation it is common to term the world - wide international level „International" in contrast to the „European" level, which, however, of course also has an multi-national character.

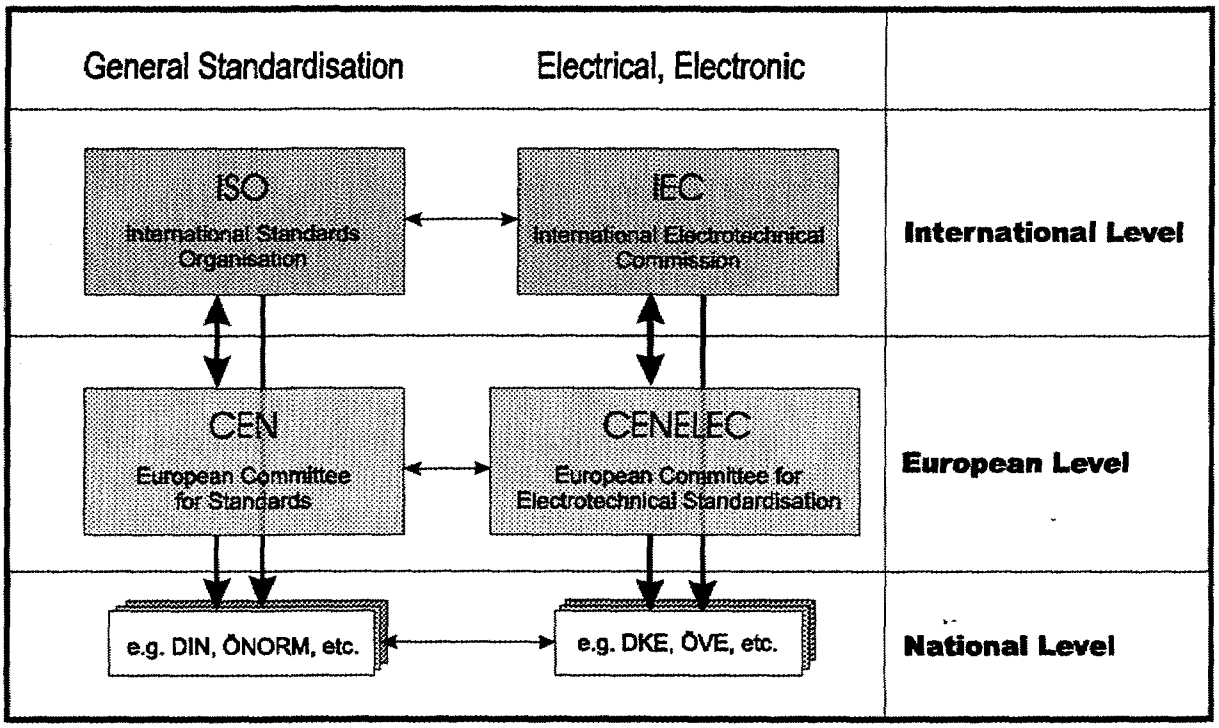

Figure 1: Differentiation of Standards Organisations in terms of electrical and non-electrical subject groups and in terms of levels of internationalisation.

Traditionally, in terms of subject areas, the field of standardisation is split into organisations which deal with electrical and electronic engineering, and into organisations which deal with other subject areas such as mechanical tools, protective clothing, photography and quality management. This differentiation exists on an international level (IEC-ISO), on the European level (CENELEC - CEN) and also often on national levels. However in some countries only one national standards body publishes both electrotechnical and non-electrotechnical standards.

In terms of the „internationality", the European viewpoint distinguishes between three levels: world-wide international, European and National. World-wide international standards organisations comprise „National Committees" (IEC) or „Member Bodies" (ISO) as members on the national level. For Europe, there are also two corresponding standards organisations, CENELEC and CEN, which are responsible for European standards and which have the national standards organisation of the European Union as members. Hence the national standards organisations in Europe are members of not only the corresponding international organisation but also of the European organisation.

Brought about by a rapidly expanding world-wide market and corresponding need for efficient use of resources and by the wish to decrease friction losses, the degree of these differentiations has decreased considerably over the last couple of years for all levels of standardisation, bringing not only electrical and non-electrical standardisation into closer contact but especially international and European standardisation.

2.1 Electrical vs. Non-Electrical

With ever increasing numbers of standards, there is interest in unified terminology and a standardised approach to numbering of standards in order to simplify matters. Therefore ISO and IEC have defined common directives to deal with these organisational issues. These directives are published as three parts:

1. Procedures for the technical work
2. Methodology for the development of International Standards
3. Drafting and presentation of International Standards

Similar directives exist also for CEN and CENELEC with the same goal of „standardising" starndards.

In addition to these matters of organisation, procedures and methodoly, subject related mutual interests also often exist, especially with new technologies such as lasers. In some fields, such as safety standards for machines, it is often not clear if the mechanical or electrical safety aspect dominates. In such cases the corresponding working groups of interested parties and experts working on new projects often look very similar. To prevent duplication of effort in such cases, ISO and IEC establishes joint working groups to ensure efficient coordination and the widest possible global application.

In the field of laser technology there are aspects of both non-electrical and of electrical character - the agreement between ISO and IEC is such that „optics", „measurement" and „machines for materials processing" are the responsibilty of ISO and other aspects, especially the ones relating to safety, are dealt with by IEC. For further information see the paragraphs on the scope of the respective committees below.

For completeness it should be mentioned that on the European level besides CEN and CENELEC there is a third standards organisation, ETSI, which deals with telecommunication. However, there are no ETSI standards (ETS) which are relevant to laser safety.

2.2 TC's, SC's, WG's

Both on the international and on the European level, the organisational units which are responsible for the creation of new standards and updating (amending) existing standards are the „Technical committees", TC (see Figure 2), such as „IEC TC 76" which deals with „Optical Radiation Safety and Laser Equipment". Other TCs deal for instance with product groups such as lamps, the electrical safety of medical products, protective equipment, optics, etc. The technical work done in the various TC is coordinated and followed up on by the Technical Bureau (BT) at ISO, CEN and CENELEC; the corresponding organisational unit is called Committee of Action (CA) in IEC.

A TC usually meets once a year and consists of delegates which are nominated by the national standards committees - IEC TC 76 for instance has about 150 members. Especially for larger countries usually more than one delegate is present at the meeting, however for formal votes in the plenary session of the TC, each country only has one vote - the national delegation or delegate has to represent the interest and the opinion of their national committee. In ISO and

IEC, national standards organisations can have P-Member status (Participating Member) or an O-Member status (Observing Member). The status of a national committee can vary from TC to TC, depending on the extent of interest and participation of the national committee in the work done by the respective TC.

P-member	**O-member**
participating	*oberserving*
obligation to vote	no obligation to vote
supposed to attend TC meetings	free to attend TC meetings
receives all documents	
submit comments on draft standards	
vote on new work proposal	can not vote
vote in committee draft stage (CDC)	can not vote
vote in CDV, FDIS stage	
WG participation	can not participate in WGs

Due to the obligatory nature of participation in the European standardisation activities, there is only one status of membership for CEN/CENELEC, which is equivalent to the P-membership.

In addition to subdividing a TC into Working Groups, for very large TC's another organisational level comprising „Sub-committees", SC, might be installed, as is the case for instance with ISO/TC172 „Optics and optical instruments" where SC9 deals with „Electro-optical systems".

The actual work of writing the standard is done in the different Working Groups (WG) of the TC or SC. The Technical Comittee IEC TC 76, for example, currently is comprised of 9 Working Groups, which will be listed further below. Within a WG, the members are not considered national delegates, and as experts in the field can advocate their own standpoint. In practice an expert member of a specific Working Group will usually also be a national delegate or part of the national delegation to the respective TC.

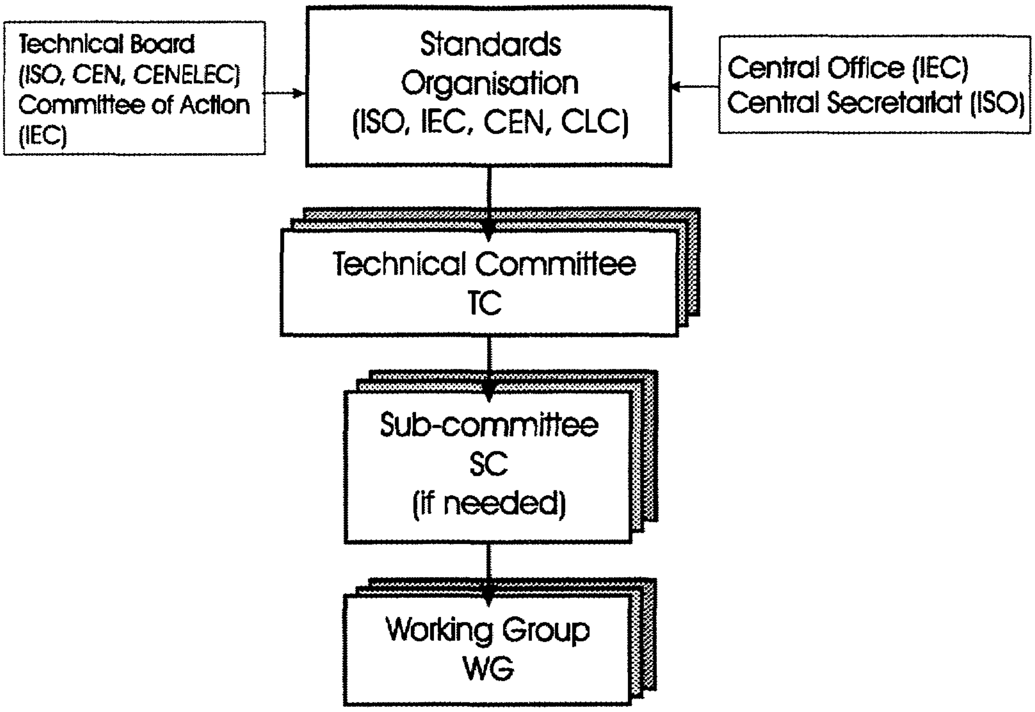

Figure 2. Hierchical structure of international and European standards organisations

It is important that the national committees are kept informed by their experts and delegates on the work performed in the Working Groups and on the activities of the TC, as the national committees have to comment and vote on the draft standard which was developed by the WG and approved by the TC. It regularly happens that there is consensus among the national delegates regarding a document at the plenary session of a TC meeting and later the document is voted down by several national committees, resulting in considerable delays.

2.3 The Way to an International Standard

International Standards are developed by ISO's and IEC's technical committees by a six step process, which is defined in the IEC/ISO directives:

Project stage	Name of associated Document	Abbreviation of Document	Voting Period
1 Proposal stage	New work item proposal	NP	3 months
2 Preparatory stage	Working draft(s)	WD	no vote
3 Committee stage	Committee draft(s) (IEC: Committee Draft for Comment also used)	CD CDC	individual
4 Enquiry stage	Draft International Standard (ISO) Committee Draft for Vote (IEC)	DIS CDV	5 months
5 Approval stage	Final draft International Standard	FDIS	2 months
6 Publication stage	International standard	ISO, IEC	-

Stage 1: Proposal stage

The first step in the development of an International Standard is to confirm that a particular International Standard is needed. A proposal for new work generally originates from a national standards organisation. A new work item proposal (NP) is submitted for vote to the national standards organisations; often this new work item proposal consists only of the title of the new project, such as „Beam delivery systems for high power lasers".

The proposal is accepted if a majority of the P-members of the TC or SC votes in favour. Upon acceptance of the proposal, target dates for the development of the standard are set.

Stage 2: Preparatory stage

Usually a working group is responsible for the preparation of a working draft. If a WG whose perview covers the new work item does not exist yet, a working group of experts, whose chairman (convener) is the project leader, is set up by the TC (or SC). The working drafts are documents which circulate only in the respective WG and the document is refined by the WG until the working group is satisfied that is has developed the best technical solution to the problem being addressed. At this stage the draft is forwarded to the working group's parent committee (TC or SC) for the subsequent international „consensus-building" phase.

Stage 3: Committee stage

The document forwarded by the working group to the TC is registered by the Central Secretariat of IEC or ISO, respectively. The document in this stage is called CD, „Committee Draft" (in IEC such a document is also regularly called CDC „Committee Draft for Comments" to prevent confusion with the Committee Draft for Vote, which is the next stage in IEC).

A number is assigned to the document by the TC and it is subsequently sent out to all national standards member organisations. The document is distributed in turn by the national standards organisations to the members of their corresponding national experts group (e.g. the national committee which deals with „Laser"). The national committees discuss the CD and formulate comments which should represent the national consensus of interested and involved parties. These comments are sent back to the TC together with a vote. The TC collects the comments and forwards them to the WG, which is oblidged to review every comment and to adopt it for the draft document if it is deemed beneficial to the draft document. All comments by the national members and the corresponding reaction by the WG are collated and redistributed to the national members (Compilation of Comments, „CC"). If the vote on the CD was positive, then the document (after being revised following the comments) can go on to the next stage, where it becomes a CDV if it is an IEC document or a DIS if it is an ISO document. If the CD was rejected, another CD must be prepared which addresses the negative votes. Hence successive CDs may be needed until consensus is reached on the technical content.

If the preparatory stage already yielded a mature document for which a wide consensus can be expected, the TC can decide to skip the committee stage (CD) and proceed from a working document directly to an ISO DIS or an IEC CDV.

Stage 4: Enquiry stage

The ISO DIS (Draft International Standard) or IEC CDV (Committee Draft for Vote) is circulated to all national members for voting and comment within a period of five months. If a two-thirds majority of the P-members votes in favour and not more than one-quarter of the total number of votes cast (P-members plus O-members) are negative, the CDV is approved to move on to the next stage. Whereas a CDC is a document which invites international discussion and comments, a CDV usually is at a more mature and less controversial stage.

Correspondingly, if comments are received suggesting changes which are deemed extensive by the TC, they can not be acted upon at this stage, but are rather filed for consideration during the next revision of the document.

If the approval criteria as described above are not met, the text is returned to the originating committee for further study and a revised document is again circulated for voting and comment as an ISO DIS or a IEC CDV.

Stage 5: Approval stage
The final draft International Standard, FDIS, is circulated to all national members for a final Yes/No vote within a period of two months. Basically only editorial changes can be considered at this last stage of a draft standard. If technical comments are received during this period, they are no longer considered at this stage, but registered for consideration for a future revision of the International Standard.

The text is approved as an International Standard with the same criteria as given for Stage 4. However it is rare that a document which has reached the FDIS stage is not accepted for publication as a standard.

Stage 6: Publication stage
Once a final draft International Standard has been approved, only minor editorial changes such as the correction of typographical errors can be introduced into the final text. The final text is sent to the Central Secretariat of IEC or ISO respectively, which publishes the International Standard.

Review of International Standards
All International Standards are reviewed at least once every five years by the responsible TC or SC respectively. A majority of the P-members of the TC or SC decides whether an International Standard should be confirmed, revised or withdrawn.

2.3.1 The way to an European Standard

The development stages of CEN and CENELEC standards are equivalent to the stages as described above for international standards; one important difference is that there are votes on documents only in the DIS (CDV) and in the FDIS stage. In the development scheme for CEN and CENELEC, the committee draft stage, stage 3, is implemented only to invite national committees to comment the draft but not to vote on it.

It should be noted that due to recent agreements between the international standards organisations and their respective European counterparts, most standards are developed on the international level and voted in parallel as International Standards and at the same time as European standards, where the European parallel voting starts at the Enquiry stage where the document is an ISO DIS or a IEC CDV. This is the topic of the following section.

2.4 EUROPEAN DIRECTIVES - THE NEW APPROACH

In the past, the European Community agreement allowed members to publish special control mechanisms if there were well-founded public health concerns. This caused technical trade barriers, since each country had its own safety requirements.

In 1987 the members of the EC decided to harmonise technical requirements in order to eliminate trade restrictions. The common policy of regulations in the product safety sector is based on a whole string of Directives which must be fulfilled by a product before it can be distributed or sold.

The policy which is followed currently is called the „New Approach" and it is based on four principles:

a) legislative harmonization is limited to the adoption, by directives, of the essential safety requirements or other requirements of general interest

b) the task of drawing up the technical specifications needed for the production confirming the directive is entrusted to organizations responsible for standardization

c) the technical specifications are not mandatory and maintain their status of voluntary standards

d) national authorities are obliged to recognize that products manufactured in conformity with harmonized standards are presumed to conform to the „essential requirements" established by the directive.

In Europe, standardisation has gained considerable importance since the realisation of the New Approach in 1992. Following the New Approach, the European Directives contain only basic and very broadly defined safety goals, or „Essential Requirements," and the specific technical realisation of these safety goals is contained in European standards.

Previous to the New Approach, the Directives which were issued to facilitate the free circulation of goods were linked with detailed Annexes which specified technical requirements. To keep these Annexes up-to-date proved to be very difficult as an unanimous vote was required to change a directive. Since the introduction of the „New Approach", the directives define mandatory essential requirements as a common basis for national regulation, and CEN/CENELEC is mandated to develop harmonised standards to provide the interpretation and detail in support of the Directive. Compliance to „New Approach" directives is indicated by the „CE" mark.

It should be pointed out however, that although it is mandatory for the national members to publish the European standards as national standards, the application of the standards by the manufacturer is voluntary, as long as he can prove that the „Essential Requirements" are fulfilled. In practice however, manufacturers are under considerable pressure to conform to these standards - indeed compliance to the European Standards provides the only economic method to demonstrate conformity to the „Essential Requirements".

At the moment there are three directives that are most important for the manufacturing and use of lasers in the field of laser materials processing:

- 89/392/EEC *Council Directive on Machinery*
- 89/686/EEC *Directive on Personal Protective Equipment*
- 89/656/EEC *Directive on the Use of Personal Protective Equipment*

Other directives which might be applicable for laser products are the *Low Voltage Directive* and *Electromagnetic Compatibilty (EMC) Directive* and for medical laser products the *Directive on Medical Products.*

It should be noted that „European compliance" as such and the corresponding CE marking of the product implies compliance to *all* Directives which are applicable to the product.

2.4.1 The principle of Risk Assessment

The EC Directives, and in particular the Machinery Directive, require manufacturers and employers to carry out risk assessment of the product or the working place, respectively. Risk assessment involves the identification and evaluation of possible hazards and the extent of possible injuries due to these hazards. A combination of these two parameters results in a specific level of risk, which has to be acted upon.

The EC Directives specify a sequence of actions following the risk assessment

- eliminate the risk
- substitute the hazard for a lesser one
- isolate the hazard
- control by making it difficult to get at the hazard
- give training and discipline to everybody with warnings, instruction and supervision
- if the risk can not be eliminated, provide personal protection

Also it is policy of the international standards organisation to employ the principles of risk assessment to the development of standards (e.g., as laid down in *IEC Guide 51*). The standards such as the IEC standard on guards IEC 60825-4 and the ISO standard ISO 11553 on the safety of laser processing machines, which are reviewed below, are based on the principle of risk assessment.

The risk assessment approach in contrast to the prescriptive approach has the benefits of being more flexible and of leaving the possibility open for individually optimised solutions for a specific product or situation. In contrast, the prescriptive approach of standardisation has to take account of all possible hazardous situations and has therefore often led to over-restrictive control measures for specific situations (e.g., for laser guards, the prescriptive approach was sometimes referred to as the „fortress enclosure“ approach). The risk assessment approach produces standards which guide the user of the standard to identify all possible risks and then to take appropriate actions.

2.4.2 Physical Agents Directive

The new approach as discussed above applies only to matters falling under Article 100A of the EEC treaty, which are matters concerning the internal European market and industrial affairs. For matters concerned with employment and social affairs, Social Directives are applicable and these still follow the old approach. One such example is the draft version of the *„Physical Agents Directive“*, whose aim is to define limit values in order to protect workers from harmful influence of physical agents such as noise, electromagnetic radiation, and optical radiation (including laser radiation). Following the old approach, limit values are specified in the Annex of the Directive. For the part dealing with laser radiation, it must be noted that concepts of ceiling levels, threshold levels and action levels are employed which come from the field of noise and vibration but which should not be applied to laser or optical radiation. In the field of laser safety, the classification system has been developed to give the user information on the possible hazards of the product so that the user does not have to deal with threshold limit values for optical radiation, which are complicated, difficult to measure and prone to misinterpreation.

Currently the directive is at a draft stage and is not further pursued by the European Union, due to heavy protests from several governments.

2.5 International vs. European Standards

There is an important difference between the status of international standards, i.e., ISO and IEC, and the European Standards. This difference is mainly due to the European „New Approach", according to which „Essential Requirements" are defined in Council Directives in general and rather broad terms and European standards which specify detailed technical specifications as a way to achieve these essential requirements. The national members of CEN/CENELEC are required to adopt all European Standards in identical form as national standards. Only a national front-page (foreword) may be added, where comments and information can be included which relate to national peculiarities. Other national standards which deal with the same subject must be withdrawn. IEC and ISO standards on the other hand are not binding for the national members, but can be adopted as national standards. As an example, ANSI, the American National Standards Institute, publishes ist own set of laser safety standards, which are not harmonised with the equivalent IEC standards.

For this reason, Euronorms have a much greater importance for European members than International Standards.

2.5.1 Types of Standards

According to the varying degree of obligation of implementation on the Eurpean level, there are four basic types of CEN/CENELEC documents (Definitions from CEN/CENELEC „Internal Regulations"):

European Standard (EN)
CEN/CENELEC standard that carries with it the obligation to be implemented at national level by being given the status of a national standard and by withdrawal of any conflicting national standards.

Harmonisation Document (HD)
CEN/CENELEC standard that carries with it the obligation to be implemented at national level, at least by public announcement of the H.D. number and title and by withdrawal of any conflicting national standards. *Comment by the Author:* national differences in the corresponding national standard are permitted, however the national standard has to have the same technical content. A HD does not have to be published as a national standard, however conflicting national standards have to be withdrawn. It is also possible that only part the technical content of the HD is used in a national standard which for instance has a somewhat different or broader scope than the HD.

European Pre-Standard (ENV, from the German: „Vornorm")
Prospective standard elaborated by CEN/CENELEC for provisional application, while conflicting national standards may be kept in force in parallel.

CEN/CENELEC Report
CEN/CENELEC publication, authorised by the Technical Board in order to provide information. *Comment by the Author:* a report has the character of a guide or a collection of expert knowledge.

On an international level there are only two relevant types of standards: ISO and IEC standards as such, and ***„Technical Reports"*** with the abbreviation „TR". A technical report (in IEC the full designation is „Technical Report Type 3") has a similar nature to a CEN/CENELEC Report. It is often used for Guidelines intended to give information for laser users, such as

IEC 825-3 on the safety of laser displays (shows) and the draft IEC 61389 „Guidelines for the safe use of medical laser equipment". Also a future standard on laser safety measurements as developed by WG3 of IEC/TC 76 may become a technical report. The content of the standard will rather be a compilation of possible ways to measure safety-related parameters and to point out pitfalls and sources for errors. As there are several acceptable ways of measuring safety-related parameters in order to realise the test requirements as specified in IEC 825-1, the nature of the document is not to standardise these measurments but rather to give guidance in a complicated technical field.
In IEC, a *technical report type 1* can be published when the required support for the publication of an International Standard can not be obtained despite repeated efforts. A *technical report type 2* can be published when the subject is still under technical development or for any other reason where there is the future but not the immediate possibility of an agreement on an International Standard. However, so far only technical reports type 3 have been published in the field of laser safety.

2.5.2 „Laser" Committees, Agreements

The globalisation of the market gives rise to pressure for world-wide international standards which are also published as Euronorms with an identical content.

Presently about 90 % of the standards published in Europe by CEN and CENELEC have their origin as international standards of ISO and IEC, respectively.

The committees dealing primarily with lasers and laser radiation on a European and international level are represented in Figure 3. Whereas the electrical committees on the one hand and the non-electrical committees on the other are responsible for different aspects of laser standardisation, the work on the international level and on the European level was often duplicated.

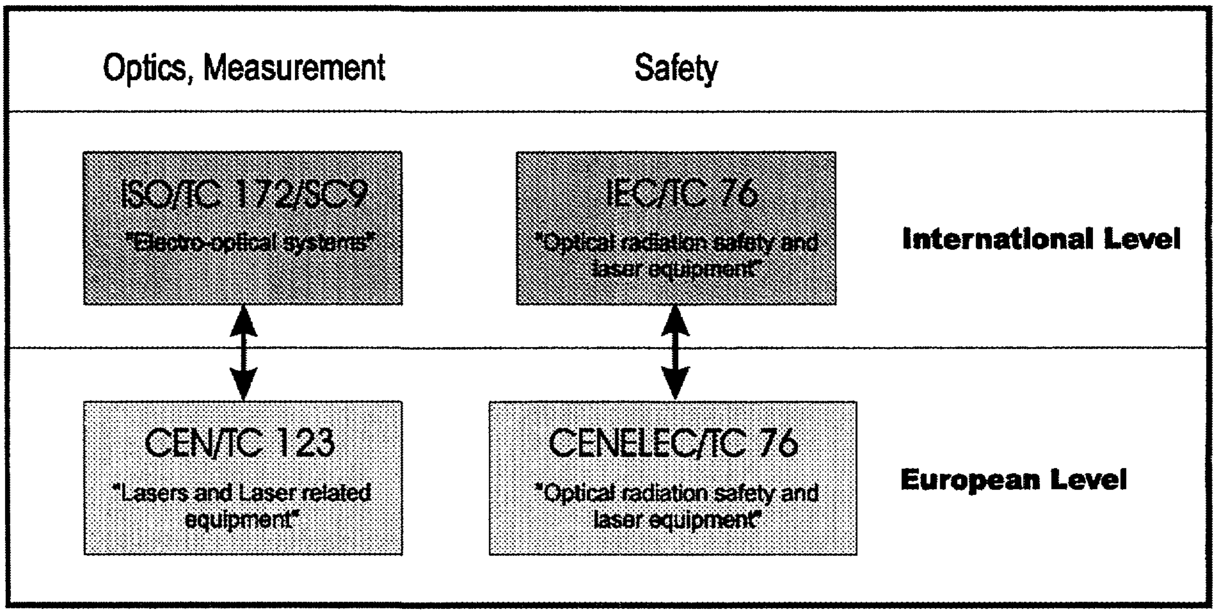

Figure 3: TCs dealing with „Laser" of ISO and IEC and their corresponding TCs on the European level.

To increase the efficiency of standards development, the collaboration of the International Standards organisation with their European counterparts was reorganised. The object of the agreements between ISO and CEN on the one hand and IEC and CENELEC on the other were to speed up the preparation of standards and to ensure the best use of available resources, and particularly of expert's time.

The motto is „Do it once, do it right, do it internationally."

The cooperative agreements „Dresden Agreement" between the IEC and CENELEC and the „Vienna Agreement" between ISO and CEN relate to two aspects of standardisation:

- common planning of new work
- parallel voting at the international and the European levels

2.5.2.1 New Work

When a new work item is considered necessary by CEN or CENELEC, the organisation consults ISO or IEC, respectively. Corresponding to the Vienna Agreement, the Dresden Agreement between IEC and CENELEC has a more stringent character. As soon as IEC decides to take on the work, CENELEC can no longer continue working on the project. IEC keeps CENELEC informed month by month of the state of progress of the work and of any difficulties which may have been encountered. Only if IEC decides not to pursue the project can CENELEC go ahead, which finally results in a European Norm which did not originate as IEC standard. Corresponding to the Dresden Agreement, all but one working group of CENELEC/TC 76 are not active and can be considered „shadow" working groups which may become active if CENELEC/TC 76 has the impression that the development of a standard project which was initiated by CENELEC is not progressing in IEC/TEC76 as agreed. An example of work done by CENELEC according to the agreement is the development of a standard on laser safety training. IEC/TC 76 decided in 1995 not to pursue this new work; hence the work was begun by CENELEC/TC76/WG4.

The relationship between CEN and ISO according to the Vienna Agreement is rather based on equal rights: if there is mutual interest, either the ISO or the corresponding CEN TC can take the lead in producing the standard. However, generally ISO will take the lead. Consequently, CEN/TC 123 decided at its last meeting in Glasgow to disband all its working groups, as the technical work was done by ISO/TC172/SC9. The editorial and managing work necessary for adoption of the laser standards on the European level is provided by the secretariat of CEN/TC 123.

2.5.2.2 Parallel Voting

The regulations for parallel voting on a document at the national level as an international standard and as an identical European standard applies to both DIS (CDV for IEC) and for FDIS documents. Again, parallel voting is mandatory for all IEC-CENELEC documents but is decided on an individual basis for ISO-CEN documents.

Due to the mandatory nature of European Standards, which is not the case for international standards, a national committee may be led to cast a positive vote in the IEC and a negative vote in the CENELEC. If the results are positive in both the IEC and CENELEC, the IEC will publish the international standard, while the European standard will be ratified by the CENELEC Technical Board. If the voting results are negative in CENELEC, the Technical Board will decide on further action to be taken, for example by common amendments. If the voting results are negative in the IEC, the draft is referred back to the TC or SC concerned, and the CENELEC Technical Board decides what action is to be taken at the European level.

2.6 SYSTEMISING DOCUMENTS

A standard is clearly identified by either its title but also by its number. However, as there may be more than one than edition of the same standard, it is prudent to also add the year of publication at the end of the standard's number.

2.6.1 Numbering of Standards

The system of numbering of standards which originated on the international level is shown with the example of ISO and an IEC standards in the tables below. Generally the numbering scheme should insure that the international origin and equivalence of the (national) standard can be easily identified.

In the numbering system currently „used by CEN, the letters „ISO" are kept in the numbering scheme of the European standard, adding the „EN" if it is a European standard. Also at the national level, the letters of the corresponding national standards organisation is added and the original EN number is retained. At the international level, „DIS" indicates that it is a draft international standard, however at the European level, the „EN" changes to „prEN" for draft standards (see second expample). Upon publication of a draft standard by the national standards organisations, both „pr" and „DIS" are dropped from the number of the standard, which sometimes makes it difficult to identify the status of the document if only the number is available.

International	ISO 11255:1994	ISO/DIS 11146:1995
European	EN ISO 11255:1994	prEN ISO 11146:1995
National, *example*	DIN EN ISO 11255:1995	DIN EN ISO 11146:1996

It should be noted that EN standards with ISO origin which were published before 1994 were denoted *without* the letters „ISO", but 20000 was added to the ISO standards number to indicate its origin as an ISO standard; for example ISO 11252:1993 was published as EN 31252:1994.

The IEC/CENELEC system is slightly different, as „IEC" is dropped upon publishing the standard on the European level. Prior to 1997 CENELEC added a „60" in front of the three digit IEC number (i.e. 60000 was added to the IEC standard number) to indicate the origin of an IEC standard, thus making EN 60825 out of IEC 825 (see table below).

Since the beginning of 1997, IEC has changed its numbering system to harmonise it with the CENELEC numbering system. Beginning in 1997, IEC standards numbers will also start with „60" - this applies to future standards and also to new editions of existing standards (as can be seen for example at the final draft of IEC 60825-4). It should be noted that in its database, the IEC has also changed existing standards to this new numbering scheme; thus the currently valid IEC 825-1 can be found in the database as IEC 60825-1. Publications printed before 1997 will continue to carry the old series of numbers on printed copies until they are revised, but these older publications will appear with the new 60000 numbers in both bibliographic reference material and on invoices. At the same time, all project numbers relating to work in progress in the IEC have also been renumbered in accordance with the same principles.

International	IEC 825-1:1993	IEC/FDIS 60825-4:1997
European	EN 60825-1:1994	prEN 60825-4:1997
National, *example*	DIN EN 60825-1:1994	DIN EN 60825-4:1997

Beginning in 1997, numbers 1 - 59999 are reserved for ISO standards, and 60000 to 79999 are reserved for IEC standards.

As at the time of this writing the transition to the new IEC numbering system is not fully completed and the IEC primary standard for laser safety is still generally known as IEC 825-1. Therefore, the 60000-numbers will only be used in this chapter for documents which are still in the draft stage.

2.6.2 Languages

The official languages of ISO and IEC are Russian, English and French; however standards are only published in English and French. On the European level, the documents are published in English, French and German. National committees are free to translate the European Standards into other languages for publication as national standards.

2.6.3 Amendments, Corrigenda

A standard is updated by amendments, which have draft document stages and votes equivalent to a new standard, as described above. Amendments are abbreviated by „A“ and consecutive amendments are numbered, such as A1 and A2. These amendments regularly contain corrections to single paragraphs, sentences or even words for the text of the standard which is to be updated. This often resulted in an accumulating patchwork of corrections and changes. Therefore IEC recently introduced a policy to publish each Amendment on its own, as was previously the case, but also to publish a full document with the changes as contained in the amendment already included in the whole text.

Additionally, to distinguish between different editions of standards, the year, or the year and the month of publication is added to the standards number, such as EN 60825-1:1994 + A1:1996. The information on the date of publication is particularly important if there is more than one edition of a standard - a new edition of a standard is usually published following extensive changes. Also instead of publishing a third amendment, the revised text is published as a new edition.

If only editiorial changes, i.e., no technical changes, have to be published for a document, this is done in a Corrigendum, which is identified by the month and year of publication, such as EN 60601-1:1990 + Corr. July 1994.

2.6.4 Horizontal vs. Vertical Standards

Standards are grouped into a horizontal and vertical hierarchy. Horizontal standards are applicable to a broad group of products, whereas vertical standards are applicable to specific subgroups. An example for different horizontal standards would be „Safety of medical equipment“ „Safety of machines“ and „Safety of laser products“. The requirements laid down in the horizontal standard, for instance in the „Safety of medical products“ standard are applicable to all medical products; a range of vertical standards could then be related to this horizontal standard dealing with safety requirements specified for medical lasers, electrocardiographs, ultrasonic probes, etc. The vertical standards can specify specific requirements applicable only to the subgroup; however the requirements of the horizontal standard would also be applicable.

Horizontal standards usually are numbered as „Part 1", with a „-1" placed after the standard number, e.g., EN 60601-1 for the electrical safety of medical equipment or EN 60825-1 for laser products. Vertical standards can then be „Part 2", „Part 3," and so on, as for laser equipment (EN 60825-2 for optical fibre communication, EN 60825-3 for laser shows), etc. Vertical standards can also be numbered consecutively as a list of different subparts of part 2, as for instance EN 60601-2-22 for medical laser equipment.

EN 60601-1	Medical electrical equipment - Part 1: General requirements for safety
EN 60601-2-22	Medical electrical equipment - Part 2: Particular requirements for the safety of diagnostic and therapeutic laser equipment
EN 60825-1	Safety of laser products - Part 1: Equipment classification, requirements and user's guide
EN 60825-2	Safety of laser products - Part 2: Safety of optical fibre communication systems
EN 60825-3	Safety of laser products - Part 3: Guidance for laser displays and shows

As can be seen at the example of the standards in the table, the first part of the title corresponds to the base standards number.

2.6.5 The European Approach to Hierarchy

In the light of the „New Approach" it was felt in CEN/CENEC, that the general hierachical categorisation of standards into horizontal and vertical standards is not the ideal background for a structured development of a large number of standards. The Eurpean approach to group standards into a hierachy is laid down in the standard EN 414: *„Rules for the drafting and presentation of safety standards"*.

In this standard, three types of standards are defined:

- Type A are fundamental safety standards
- Type B are group safety standards
- Type C are machine safety standards

An example for a Type A standard is the standard EN 292: *„Safety of machinery- Basic concepts, general principles of design"*. This is a fundamental safety standard which was developed to specify in detail the essential requirements as contained in the „Machinery Directive". However, EN 292 does not contain specific requirements for groups of machinery, such as for laser processing machines. This specific information is contained in a Type B standard, i.e. EN 12626 *„Safety of machinery - Laser processing machines - Safety requirements"*. At the time of this writing there are no projects to develop Type C standards for laser processing machines; such standards would specifiy the requirements of EN 12626 on a more detailed level for specific kinds of machinery.

2.6.6 Numbering of TC documents

All documents originating from a specific TC and intended for official distrubution outside of working groups carry a document number which is asigned by the secretariat of the TC. This numbering scheme is equivalently used by ISO, IEC, CEN and CENELEC.

The number of a specific document consists of:

1. the number of the TC or SC from which the document emanates
2. a unique document number in a single chronological series for each TC or SC
3. a letter code indicating the type of the document, such as a CD or FDIS

An example is IEC 76/156/CD, which is a document originating from TC 76, and is the 156th document which has been circulated by TC 76. In this case it is a committee draft.

In addition to consecutively numbering the documents of a TC, the projects of a TC (the different development projects for standards or amendment to standards) are numbered. An example is 76/61389/TR3/Ed.1, an IEC TC 76 project to develop „Guidelines for the safe use of medical laser equipment", which will be the first edition of a Technical Report with the number IEC 61389. The IEC 76/156/CD document mentioned above is actually the second Committee Draft of this particular project.

3 OVERVIEW OF LASER SAFETY STANDARDS

In the field of laser safety, the standard IEC 825-1 „*Safety of laser products - Part 1: Equipment classification, requirements and user's guide*", represents a base document which is applicable to all laser products and installations (IEC 825-1:1993 is identical to EN 60825-1:1994). In terms of hierarchy (see paragraph 2.6.4), IEC 825-1 is a horizontal standard and has the role of a „Group Safety Publication". It specifies requirements for manufacturers of laser equipment, such as the classification into hazard classes, labeling and technical requirements. It also specifies actions which should be taken by the user of laser equipment to ensure safe application. As a horizontal standard, IEC 825-1 concentrates on the hazards presented by the laser radiation to the eye and the skin. It only gives limited information on electrical safety and other hazards such as fumes associated with the application of lasers.

Figure 4 is a graphical presentation of the groups of standards relevant to laser materials processing in the framework of the European Union.

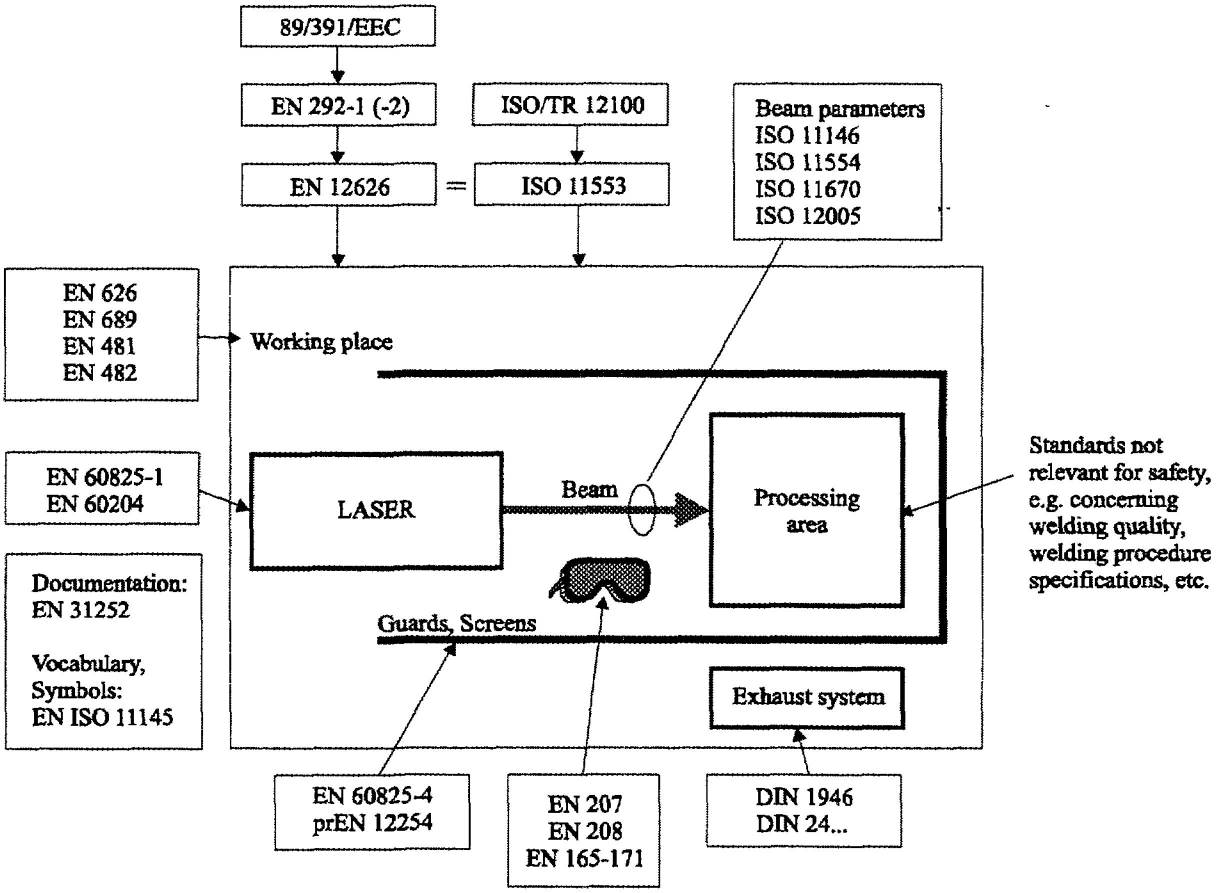

Fig. 4 Safety standards related to laser material processing

The following groups of standards can be identified (See Figure 4, starting from the upper left and proceeding clockwise). The scope of the standards are described in detail in the following sections, and a list of standards can be found in the appendix.

- Following the „New Approach", the Machine Directive 89/391/EEC mandated a base standard on machine safety of Type A, EN 292. EN 12626 as a standard Type B contains specific requirements for laser processing machines. On the international level, ISO has based its technical report ISO/TR 12100 on EN 292, and ISO 11553 is technically equivalent to EN 12626.
- ISO published a series of standards dealing with the measurement and testing of beam parameters such as power, energy, beam stability and polarisation. However it should be noted that these standards do not apply to safety measurements but to performance parameters of lasers.
- Also included in the database were standards relating to the quality of welding, which are not relevant for safety issues.
- Several standards of DIN origin relate to the performance of the exhaust system.
- Technical specifictions for the testing of laser eye-protection are contained in EN 207 and EN 208. The standards series EN 165 - to EN 171 relate to general requirements for eye-protection.
- Requirements for guards are laid down in EN 60825-4. EN 12254 has been mandated by the *Commission of the European Communities.* However, due to an overlapping scope with EN 60825-4, the technical contents of EN 12254 will be contained in the appendix of the next edition of EN 60825-4.
- The standard EN 31252 *„Laser device - Minimum requirements for documentation"* (idt. ISO 11252) does contain specifications for the information for users; however, this information is not safety-related but rather concerns the technical parameters of the laser device. Similarly, the standard EN ISO 11145 *„Lasers and laser related equipment - Vocabulary and symbols"* was developed not specifically with laser safety in mind. In fact the differences in terminology between ISO 11145 and IEC 825-1 were the topic of several discussions between the relevant TCs. The specific issues of the hierarchical stages and definitions of „laser equipment", „laser systems" and „laser products", seem to be resolved now, and an informative Annex A will be included in the next issue of ISO 11145, with an explanation of the differences between this document and to IEC 825-1.
- EN 60204 specifies requirements for the electrical safety of machines and thereby also applies to laser processing machines.
- EN 60825-1 is the base standard for laser equipment
- EN 626 is another Type B standard under EN 292 *„Safety of machinery"* and relates to hazardous substances emitted by machinery.
- EN 481 and EN 482 deal with issues of measurements of airborne particals and chemical agents in workplace atmospheres.

3.1 EU 643 AND ITS IWG 6 „NORMS AND STANDARDS[1]"

As early results were obtained in the framework of the Eureka EU 643 (Industrial Laser Safety) project, it was realised that such a major effort in financial and man-power resources should ideally result in input to the relevant standards projects or even result in new standards development projects.

Traditionally a standard was developed after a group of products and the knowledge about the potential hazards reached a certain completeness and maturity. However due to rapid progress in new technical fields, it was felt prudent to stress the importance of standardisation at the research and develoment stage of a project. Thereby it is hoped that the early definition of common industrial standards can be achieved. Hence the Eureka umbrella organisation published a Guide to Standardisation for Companies Involved in EUREKA Projects which is intended as a call for action. According to this Guide, the researcher should be aware of:

- Existing standards: „which may have implications for their projects"
- Standards in the drafting stage: „which can also have an impact on research work, and where it is possible to contribute to the standardisation process"
- Fields not yet covered: „where it is essential to identify the need for standards as new technology develops, thus enhancing its commercial success"

Following the call for action by the research management of the European Union for standards generation during the research and development phase, an international working group, International Working Group 6 (IWG 6) was set up in the framework of the EUREKA project EU 643. It was the aim of IWG 6 „Norms and Standards" *(EU:643 Newsletter Issue 2: September 1994)* to seek to achieve standards recommendations concerning laser safety, under the following terms of reference:

- to evaluate the current state-of-the-art in norms and standards, including laser safety in and around the workplace and its risk assessment
- to compare the latest experimental results coming from the project with existing norms and standards
- to render advice and information to the various working groups of CEN and CENELEC.

The work of IWG 6 resulted in a list of Technical Committees and their Working Groups which are relevant in the field of laser materials processing and who could benefit from input from EU 643. The connection between normative working groups and EU 643 was established via the personal members of EU 643 IWGs who were also members of working groups of international and European standards committees. A matrix of members of EU 643 International Working Group 6 who were also members of relevant TCs and WGs was established.

[1] to distinguish standards on the European level from international standards it was suggested to call European standards „Norms", which would also have the bonus of being reminiscent of the German word „Normen" for standards.

3.1.1 TC's relevant for laser processing

CEN or CENELEC TC's working on projects related to the safety of laser materials processing are summarised in the table below:

CEN/TC 85	Eye protection
CEN/TC 114	Safety of machinery
CEN/TC 121	Welding and allied processes
CEN/TC 123	Laser and laser-related equipment
CEN/TC 137	Air Quality
CEN/TC 156	Ventilation
CENELEC/TC 76	Laser Equipment

It should be noted that according to the Dresden and Vienna Agreement, the technical work is not done by CEN/TC 123 but by ISO/TC 172/SC 9 and that CENELEC/TC 76 has only one active Working Group, WG 4, which is working on „Safety education and training". Otherwise CENELEC/TC 76 shadows the work done by IEC/TC 76.

3.1.2 Projects of IWG 6

IWG 6 produced a Terminolgy List of „Expressions", their list of Abbreviations and Units as suggested for use in EU 643. This list combines parameters which are relevant for laser materials processing with those pertinent to laser safety *(ANNEX 1 to IWG-6 minutes of the 3rd meeting in Twente, 13.12.1994).*

Close collaboration between EU 643 IWG 4 „Training" and a standardisation project was achieved on the topic of laser safety training, where a document for a standardised syllabus for the training of laser users and Laser Safety Officers was produced and discussed at the EU 643 meeting in Copenhagen in May 1995. Working Group 4 of CENELEC/TC 76 is currently working on a draft document for a corresponding European standard.

There was also some input of results from the EU 643 international working groups „Emissions, Welding" and „Radiation" to the list of possible hazards and emissions as contained now in Annex B of ISO 11553 and the corresponding EN 12626 *Laser processing machines - Safety requirements*. However the results of EU 643 were not yet compiled and represented in a way which facilitates the adoption of the material for standardisation. It is hoped that the present reviews and analysis of data as contained in the other chapters of this book will be the basis for future informative appendices of this and other standards. The existance of the data was noted during the latest meeting of IEC/TC 76 in London in 1996 and its inclusion in future revisions of ISO 11553 was suggested.

Also contacts were established with three working groups of CEN/TC 121 „Welding", where the input of EU 643's was directed through IWG 1 „Fumes", and the development of IEC 60825-4 on guards proceeded with input from EU 643.

The activities of IWG 6 are summarised in the paper *Ongoing Work in Standards Concerning Laser Safety Proceedings*, Industrial Laser Safety Forum, Copenhagen, May 1994, page 9.

4 IEC's TC 76

IEC TC 76 has been set up to develop the base laser safety standard, currently denoted as IEC 825-1 *„Safety of laser products - Equipment classification, requirements and user's guide"*. The first meeting of TC 76 was held in 1974; however, especially in recent years IEC TC 76 has been very active in producing vertical standards relating to the specific requirements of different fields of laser applications, such as industrial, medical and telecommunication applications. In 1995 the scope of TC 76 was extended to not only deal with laser equipment but also the safety of optical radiation in general. Following this the title of TC 76 was changed from „Laser Equipment" to „Optical Radiation Safety and Laser Equipment". In IEC, TC 76 is responsible for the Safety Group Function „Aspects pertaining to human safety relating to the use of lasers".

4.1 Scope

In 1995 the scope of IEC TC 76 was updated and extended to include light emitting diodes and also broadband optical radiation such as emitted by lamps, specifically:

> To prepare international standards in the field of equipment incorporating lasers (and light emitting diodes) or intended only for use with lasers, including those factors introduced by the use of lasers which are needed to characterisze the equipment and/or which are essential to safe use. The scope includes the preparation of standards defining limits for human exposure to optical radiation (100 nm to 1 mm) from artificial sources.

This extension of the scope was not without controversy: after including LEDs in the scope of IEC 825-1 (LEDs are now included whenever the word „laser" is used) it was realised that the application of the test requirements (measurement setups) as specified in IEC 825-1 to LEDs resulted in the over-classification of some LEDs as hazardous when in fact they were safe to view. Also it was argued by ICNIRP, the International Commission on Non-Ionizing Radiation Protection, that it is not the function of an IEC TC to define biological limits. It should rather be the function of IEC TC 76 to adopt the exposure limits as defined by the biophysics experts of the respective ICNIRP committee[2] and on the base of these exposure limits to define safety classifications for products and requirements for products.

4.2 Working groups, Current Projects:

The following Working Groups of TC 76 are currently (August 1997) active:

WG 1: Optical radiation safety

The main responsibilty of WG1 is to maintain IEC 825-1. Currently a Committee Draft for the next amendment of IEC 825-1 is prepared (see „Future development" below).

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[2] *ICNIRP Guidelines on Limits of Exposure to Laser Radiation of Wavelengths Between 180 nm and 1,000 µm*, Health Physics, Volume 71, pages 804 - 819.

WG 3: Laser radiation measurement

At the time of this writing, WG3 is about to produce a document which aims to provide guidance for the measurements as required in IEC 825-1 to test and subsequently classify a laser product. The measurment criteria as specified in IEC 825-1 are rather basic and no information for the acutal measurement setup or measurment system is given.

Currently the project is registered as an amendment to IEC 825-1; however, due to its propable size and scope it might become a seperate document which would then most likely be a Technical Report Type 3, for the reasons discussed in 2.5.1. However as this document is directly dependent on the measurment criteria as specified in IEC 825-1, the measurment guidance document will not be published until after the next amendment of IEC 825-1 is published.

WG 4: Safety of medical laser equipment

WG4 has developed and maintains IEC 601-2-22 *„Medical electrical equipment Part 2: Particular requirements for the safety of diagnostic and therapeutic laser equipment"*.

It is currently working on Technical Report IEC 61389, Guidelines for the safe use of medical laser equipment, which is in the phase of the second committe draft.

WG 5: Safety of fibre optics communications systems

WG5 developed and maintains IEC 825-2 *„Safety of laser products, Part 2: Safety of optical fibre communication systems"*. This document will soon be amended with *„Application notes for the safe use of optical fibre communication systems"*.

WG 7: High power lasers

WG7 is the working group of TC 76 responsible for the development of standards in the field of materials processing, with the exception of work on ISO 11553, which is taken care of by WG10. The main project nearing its completion is the standard on guards, IEC 60825-4 *„Safety of laser products, Part 4: Laser guards"*. This document has been accepted for publication as a standard and is due to be published. It is planned to include data on protective exposure limits of specific materials in a future edition of the standard, however funding of this project has not yet been established. Due to its relevance for materials processing, this document will be reviewed in more detailed below.

The workgroup has initiated work on „Guidelines for the safe design and operation of high power lasers" which is registered to become EN 60825-8.

Triggered by a document *„Safety in Fiber Optic beam delivery systems for Nd:YAG lasers"* as submitted by S.O. Roos of Permanova, it was decided in 1996 to draft a Guideline to the design and use of *„Guided Beam Delivery Systems through fibre optics and free space"*. The scope of this guide is stated as follows:

> This guide describes recommendations for the design and use of guided beam delivery systems through fibre optics and free space as used in laser processing machine applications and environments.

WG 8: Development and maintenance of basic standards

WG8 developed and maintains the technical report Type 3 IEC 825-3 „*Safety of laser products, Part 3: Guidance for laser displays and shows*"

WG 8 currently works on five projects:

Project 1 - Maintenance of IEC 825-3

In view of an Australian Code of Practice for lasers in entertainment and of work done in the US on laser beams propagated into navigable air space, the content of IEC 825-3 will be reviewed and an amendment will perhaps be drafted.

Project 2 - Label symbols

This project aims to design „*Symbols to be used as alternatives to the wording on laser safety labels*", which is currently in the CDV stage and, if accepted for publication, will become an amendment to IEC 825-1. The project is motivated by the difficulties encountered by manufacturers in providing worded warnings as required by IEC 825-1 in all the languages where the product is to be sold. If the amendment is accepted, symbols can be used instead of written warnings such as „Do not stare into the beam". However the task of designing symbols which convey such rather abstract messages has proven to be a very difficult one and the project itself is also considered somewhat controversial.

Project 3 - Manufacturers Checklist

Part 5 of IEC 825 is currently in the CDV stage and upon acceptance will be published as IEC 60825-5 with the title „*Safety of laser products, Part 5: Manufacturer's Checklist for IEC 60825-1*".

IEC 60825-5 is intended to be used by manufacturers of laser products and their agents to establish that each new or modified design complies with the requirements of IEC 825-1. The checklist is not a substitute for IEC 825-1, and it is necessary to use IEC 825-1 in conjunction with the checklist, as relevant clauses and subclauses are referred to in the text. The layout of the checklist is intended only as a guide and the document is a Technical Report Type 3. Manufacturers are encouraged by the standard to produce their own document to be used for compliance testing.

Project 4 - Terminology conformance

In 1996 the project members compared the definitions of terms in ISO 11145 *(Vocabulary and Symbols)* and IEC 825-1 for consistency and subsequently produced a proposal for an Annex A to ISO 11145 to explain the difference in terminology between the two documents. This is intended to resolve discussion of whether the ISO document should be harmonised with the IEC definitions or vice versa. In annex A it is explained where the differences exist and that they reflect the different purposes for which the two standards were developed, i.e., the IEC 825-1 vocabulary was developed on the basis of the applicability of the safety standard to manufacturers of products that are sold to end users, and not to follow-on manufacturers (IEC 825-1 is not applicable to OEM lasers).

Project 6 - Application guidelines and explanatory notes to IEC 825-1

Although this project is still in the working draft stage, it should eventually produce a technical report Type 3 intended to provide the user of the base standard IEC 825-1 with information that helps to apply and interprete the standard correctly.

WG 9: Non-coherent sources

In accordance with to the extension of the scope of TC 76, working group 9 produced a document dealing with *„Maximum permissible exposure to incoherent optical radiation"*. In the IEC this document, which is at the committee draft stage (76/151/CD) is still registered as an Amendment 2 to IEC 825-1; however, from the developement of the scope of the standard it is clear that it will most likely become a Technical Report, possibly even outside the IEC 60825-series.

The original scope of the document was to define maximum permissible exposure values for the exposure of the human eye and skin to incoherent optical radiation from artificial sources (e.g., lamps) in the wavelength range from 180 nm to 1 mm. However due to protest from both ICNIRP who see it as their role to recommend exposure limits[3] and by CIE[4], the scope of the document will be changed to one which compares exposure limits from different sources and which points out inconsistencies.

WG 10: Safety of lasers in an industrial materials processing environment

This working group is actually a joint working group with experts of ISO/TC 172/SC9/WG 3, and was set up to coordinate the work on the standard ISO 11553 on the safety of laser processing machines. Due to an agreement between the ISO TC 172/SC9 and the IEC TC76, the convener of this working group is nominated by TC 76 and the responsibility to maintain ISO 11553 rests in TC 76/ WG10. However it should be noted that all new work dealing with issues in the field of materials processing is to be done by WG 7.

As the convener of WG 7 pointed out at the TC 76 meeting in 1996, it could be beneficiary for the informational value of standard ISO 11553 to consider the results of EU 643, especially on fumes and radiation. Henceforth the WG agreed to undertake the task of updating the existing Informative Annex as the detailed information is presented.

It was also proposed in 1996 that the WG would take on a project to develop a document or annex to the current ISO 11553 which would provide additional information or detailed examples for design or testing guidance.

The content of document ISO 11553 is discussed in detail in section 5.3.

WG 11: Safety of diode emitters

WG 11 has been set up following the extension of the scope of TC 76 to include the safety of light emitting diodes. Currently WG 11 works on two projects with the goal of harmonising the basic standard IEC 825-1 with LEDs. Since the basic document does not, in a practical sense, apply to some LED applications, specific requirements for these applications are developed by WG11. However some of the work is still under discussion as the work has to be harmonised with the work of WG1, which also works on an update of requirements (which became necessary especially upon the extension of the sope of IEC 825-1 to include LEDs). Ideally, the new amendment as prepared by WG1 would take care of some of the issues addressed in these new documents. It is obvious that the work in WG 11 has to be closely

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[3] *Guidelines on limits of exposure to broad-band incoherent optical radiation (0,38 to 3 μm)*, accepted for publication in Health Physics

[4] CIE Technical Report: *Photobiological Safety Standards for Lamps*, to be published

coordinated with the work done in WG 1 to prevent inconsistencies and confusion on the part of the user of the respective standards:

IEC 60825-6, *„Safety of laser products - Part 6: Safety of products with optical sources, exclusively used for visible information transmission to the human eye"*

This standard is in the committee draft stage (76/152/CD) and would be applicable for instance for LEDs used in automobile break lights, traffic lights, displays, etc.

IEC 60825-7, *„Safety of laser products - Part 7: Optical sources for wireless 'free air' applications"*

This document is still in the working draft stage and is intended to be applied basically to IR-remote controls and free-air communication systems.

4.3 IEC 825-1

As the content of IEC 825-1 is quite extensive and the matter is multifacetted, it can not be reviewed here in detail. However it is attempted to forward background information which might help to place the content of the standard in a context in terms of its development, and its biological and technical background.

4.3.1 Scope

Below, excerpts of the scope of IEC 825-1 are reproduced:

> IEC 825-1 is applicable to safety of laser products. For convenience it is devided into three seperate sections:
>
> Section One: General, including definitions
>
> Section Two: Manufacturing requirements
>
> Section Three: User's guide
>
> Laser products which are sold to other manufacturers for use as components of any system for subsequent sale are not subject to IEC 825-1, since the final product will itself be subject to this standard.
>
> Throghout this part 1 of IEC 825-1, light emitting diodes (LEDs) are included whenever the word „laser" is used.
>
> Where a laser system forms a part of equipment which is subject to another IEC standard for safety, such as IEC 60601-2-22 for medical equipment [...], this part 1 for the safety of laser products will apply in addition to the product safety standard.

It should be noted, that section three, User's Guide, is intended to be a guideline, hence this section makes recommendations with the verb „should" for safety precautions and control measures to be taken by the user of a laser product. It is left to the user, or for instance to governmental organisations to declare the recomendations of section three as binding and to replace „should" by „shall".

4.3.2 MPEs and AELs

Maximum Permissible Exposure, (MPEs) are defined seperately for the skin and for the eye. They represent biological exposure levels, specified in the units of J/m^2 or W/m^2 as a function of exposure time and wavelength. Exposure with levels below the MPE values can be considered safe for the respective exposure time and wavelength. If the MPE for the eye or the skin is exceeded, an injury to the eye or the skin, respectively, might result. It should be noted however that there is an element of probability involved in the derivation of the MPEs, i.e., that although the chance for injury increases if the MPEs are exceeded, it does not mean that an injury occurs as soon as the MPEs are exceeded. In fact, usually the MPEs are derived by deviding by 10 the exposure value which corresponds to a 50% chance of injury. Thereby there is a certain safety factor built into the MPEs. However it should be also noted that the MPEs are defined for average healthy individuals. Some individuals may be injured at lower levels than others. The MPEs are recommended by organisations such as ICNIRP or ACGIH, and they are subsequently adopted by technical standards committees such as IEC TC 76.

On the basis of these MPEs, IEC TC 76 defines hazard classes and the potential hazards which are asssociated with each specific class. A class 1 laser, for instance, is a laser where the MPE for the eye is not exceeded for a time of up to 100 s (if the product, or rather its emission, is not intended to be viewed). A class 2 laser product does not exceed the MPEs for 0,25 seconds, which is the time associated with the blink reflex for visible radiation. According to the background and meaning of the different classes, a set of AELs (for each class one table) are derived from the MPEs by considering applicable averaging aperture sizes.

4.3.3 Past and Future Developments, The „Amendment Situation"

The reader interested in the current state and future development of the standard is referred to a paper by Dr. David Sliney *„An Overview of the IEC 825-1 Standard for Laser and LED Products and Their Use"*[5], from which the abstract is reproduced:

> The IEC Standard 825-1 is the pre-eminent international laser safety standard. Although initially intended only as a manufacturer's system-safety, product performance standard, it has grown as well in acceptance as an authoritative source for information on safe use of lasers. Emphasis in revisions of this standard has, however, centered on manufacturer's requirements and the definition of laser hazard classes and measurement procedures for classification. The initial standard, IEC 825 was first published in 1984 and drew heavily on the American National Standard ANSI Z-136.1 and the US Federal Performance Standard for Laser Products (21CFR1040). Although the IEC standard has evolved, the basic philosophy and most requirements remain unchanged. The only significant changes have resulted from new scientific data, for clarification or the need to change a clearly needless requirement which had plagued either manufacturers or users. The most significant change that took place with the second edition of the standard (i.e., IEC 825-1) has been to include LEDs as if they were lasers. This fundamental change was made at the final meeting prior to voting on the new edition, and an adequate review of the impact upon applications, underlying assumptions in the MPEs and AELs and classification measurement had not been fully studied. As a result, the major activity of IEC TC-76 during the last three meetings has related to attempts to correct problems arising from the inclusion of LEDs in the same standard. Today, IEC TC-76 has been working to develop nested sub-classes to account for the wide range of risk presented by LEDs and lasers. This has led to proposals for Classes 1A and 1B to provide a class based upon a worst-case risk analysis (1A) and a "reasonably foreseeable" definition (1B). Other sub-classes have been proposed as well.

As mentioned in the abstract reproduced above, the most significant change that took place with the second edition of the standard has been to include LEDs as if they were lasers.

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[5] from: *Proceedings International Laser Safety Conference, Orlando 1997, LIA 1997*, reproduced with permission from the Author.

In 1993, the second edition of the IEC version of the standard was published as IEC 825-1:1993. Prior to this, there were no vertical standards published as „Parts" of IEC 825, and the standard had the title IEC 825 „Radiation safety of laser products; equipment classification, requirments, user's guide". In 1993 its second edition was published as Part 1, enabling other parts to be published as vertical standards; also, „Radiation" was dropped from the title of the standards series, to allow the scope to extend to hazards other than those related directly to optical radiation, such as fumes and gases.

4.3.3.1 Electrical Safety

At about this same time, the standard IEC 820 on electrical safety of laser equipment was withdrawn. The issue of electrical safety was subsequently mentioned in IEC 825-1 but no requirements are specified there. The reasoning behind this action is that the laser product will have to comply with electrical safety standard of the group of products to which it belongs, such as IEC 60601 for medical products, IEC 60204 for machines, and IEC 61010 for laboratory equipment (here the new 60000 numbering system has been used).

4.3.3.2 The current „Amendment Situation"

Upon the publication of IEC 825-1 in 1993, CENELEC published EN 60825-1 in 1994 with the identical text, which subsequently had to be published by each of the European national members as national standards by March 1995.

Soon after IEC 825-1 was published in 1993, it became obvious that the inclusion of LEDs into the scope of the standard was premature, as the measurement criteria which had been developed for well collimated laser beams could not be applied to highly divergent sources such as LEDs. Subsequently a draft amendment to IEC 825-1 was developed, which was distributed as CDV in April of 1995; however, the balloting results were negative. Subsequently a second CDV was developed to fix the problem. The corresponding FDIS was accepted in the second half of 1997 to be published as Amendment 1 to IEC 825-1. The only negative votes, from Austria and the USA, reflected several shortcomings in the CDV and the corresponding FDIS; however, when these shortcomings were acknowledged by the TC, the document was already in a CDV stage, where substantial changes could not be realised due to the rules of IEC. On the European level however, prior to publishing the second CDV as FDIS, the text was rewritten and a table was introduced specifying measurement apertures and distances of the apertures from the apparent source, which alleviated some of the shortcomings of the IEC document. The resulting document was published as A11 to EN 60825-1 in 1996. It should be noted that although the content of the European „A11" is technically equivalent to IEC's „A1" they are complety different in wording and some technical information contained in A11 is missing in A1, such as the specification of aperture sizes for classification in the UV spectral range. Therefore, when IEC 825-1 + A1 is published, the European version EN 60825-1 + A11 will *not* be identical anymore.

4.3.3.3 The future „Amendment Situation"

Working Group 1 of IEC/TC 76 is currently preparng the next amendment for IEC 825-1, which will include the issues addressed by the current amendment and will thereby replace the current amendment. The document is currently in the working draft stage and will be distributed for comment after the WG 1 is satisfied that the document can obtain an international consensus. This document is intended as a major revision of IEC 825-1 in terms of the classification scheme, measurement criteria and also an update of the MPEs and subsequent adjustment of the AELs. Furthermore, paragraphs 8 and 9 will be restructered in order to present the specifications for testing and classification in a more logical order.

However, as the document is still under discussion in WG 1, it is too soon to comment on details.

The new amendment for IEC 825-1 will follow the parallel voting procedure in CENELEC and upon its publication by both the IEC and CENELEC, the international and the European version of the standards will again be identical.

4.4 THE PARTS OF IEC 825

As IEC 825-1 is the horizontal standard, several vertical standards have been developed to deal with specific issues which are pertinent to a certain field of application or which provide additional information in the form of a Technical Report Type 3.

For consistency with the numbering system introduced in 1997 by IEC, all standards in the list below will start with the new number 60825. The following standards have been already covered in the „Working Group" section above; for brevity the first part of the title *„Safety of laser products, Part x:"* is omitted.

IEC 60825-1 Equipment classification, requirements and user's guide

IEC 60825-2 Safety of optical fibre communication systems

IEC 60825-3 Guidance for laser displays and shows (Technical Report)

IEC 60825-4 Laser guards

IEC 60825-5 Manufacturers Checklist for IEC 60825-1 (Technical Report)

IEC 60825-6 Safety of products with optical sources, exclusively used for visible information transmission to the human eye (under development)

IEC 60825-7 Safety of products with optical sources, exclusively used for visible information transmission to the human eye (new work item)

IEC 60825-8 Guidelines for the safe design and operation of high power lasers (new work item)

4.5 IEC 60825-4

The document IEC 60825-4 *„Safety of laser products - Part 4: Laser guards"* has been developed with the scope to specify the requirements for laser guards that enclose the process zone of a laser materials processing machine. Thus it applies to all component parts of guards, including clear (visibly transmitting) screens and viewing windows, panels, laser curtains and walls. In addition, Part 4 of IEC 60825 indicates how to assess and specify the protective properties of a laser guard, and how to select a laser guard. As the machine directive is based on the principle of Risk Assessment, so is this technical report.

For a detailed review of the standard, the intersted reader is referred to the paper by Dr. Michael Green, convenor of IEC/TC 76/WG 7[6].

Currently the standard is voted on as an FDIS document, and it is expected that it will be published as a standard at the end of 1997.

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[6] *Laser Guarding: a New Standard, a New Approach*, by Michael Green, in *Proceedings, International Laser Safety Conference, Orlando 1997, LIA 1997.*

4.5.1 Technical Content

At low levels of irradiance, the selection of material and thickness for shielding against laser radiation is determined primarily by a need to provide sufficient optical attenuation, i.e. to reduce the radiation to a level which is below the MPEs upon transmission through the guard material. However at higher levels, an additional consideration is the ability of the laser radiation to remove guard material or destroy the guard - typically by melting, oxidation or ablation. These processes could lead to a penetration of material which is normally opaque to the laser radiation. The standard distinguishes two types of guards; passive and active guards.

4.5.1.1 Passive guards

A passive guard shall be designed and manufactured from a material making it impossible to prevent human access to laser radiation exceeding AEL for Class 1 under worst conditions for a length of time that is sufficient for the operator to actuate the Emergency Stop.

4.5.1.2 Active guards

In contrast to passive guards an active guard consists of a guard and a detection device which causes laser emission to stop when impact of the laser beam on the guard is detected. If the guard is exposed to levels of radiation that can destroy the guard, the system shall be shut off within a time shorter than the destruction time of the guard (i.e. shut-down shall occur before accessible laser radiation exceeds the AEL for Class 1).

4.5.1.3 Performance requirements

The standard defines several parameters which are used to specify the properties of the guard material:

PEL: protective exposure limit (PEL): the maximum laser exposure incident on the front surface of a laser guard which is specified not to penetrate the guard so that the radiation at the rear surface does not exceed the class 1 AELs. It is also important to specify the wavelength for which this PEL applies.

Maintenance Inspection Interval: the time between successive safety maintenance inspections of a laser guard.

FEL: foreseeable exposure limit (FEL): the maximum laser exposure, which is expected to be incident on the front surface of the guard for a specific setup, as assessed under normal and reasonably foreseeable fault conditions. In an informative Annex B, the standard lists valuable formulas which can aid in the assessment of the FEL for a specific situation, such as a reflection by the workpiece, and it also points out potential causes of an errant laser beam.

The general performance requirement for a laser guard is that it shall prevent laser radiation accessible at its rear surface from exceeding the class 1 AEL at any time over the period of the maintenance inspection interval. For automated laser processing machines, the minimum value of the maintenance inspection interval shall be 8 h.

The guard shall be tested at the FEL which has been identified for a specific installation.

If the PEL is specified by the manufacturer of the guard material, the user has to select a guard material with a PEL which is higher than the FEL for his specific laser installation.

4.5.2 Overlapping Scopes

It should be noted that viewing windows as part of the laser guard may also comply with standards for laser protective eyewear such as EN 207, but such compliance is not necessarily sufficient to satisfy the requirements of IEC 60825-4, due primarily to the different time duration for which the viewing window as a guard must withstand the laser radiation in comparison to protective eyewear. The guard has to withstand the expected laser radiation (FEL) for at the least the duration of the maintenance inspection interval, whereas protective eyewear (see section 6.3) has to withstand the expected laser radiation for only 10 seconds, as it is assumed that the person wearing the eyewear will move out of the laser beam during that period of time.

A more serious clash of scopes on the field of international laser safety standardisation was encountered between IEC 60825-4 and the CENELEC standard project prEN 12254 „*Screens for laser working places - Safety requirements and testing*". The EN standard has been mandated by the CEC to specify requirements for passive guards under the machine directive. The standard prEN 12254 applies to passive guards which are supervised, which is also part of the scope of IEC 60825-4 as described above. The conflict between IEC/TC 76 and CEN/TC 85 seems to be mediated at the moment, as it is planned to have a common document. In the meantime the work on prEN 12254 will be suspended until the TC76 meeting in October 1997, where a joint meeting of the experts of IEC/TC 76/WG 7 with those from CEN/TC 85/ WG 3 is planned. The plan is to include the contents of prEN 12254 in IEC 60825-4 in the form of an annex.

4.5.3 Screens

From its structure it is akin to the standards for laser eye-protection EN 207 and EN 208, as these standards were prepared by the same working group of the CEN Technical Committee CEN/TC 85. As EN 207 specifies „Protection Levels" for eye-protection, prEN specifies „Scale Numbers" which indicate the maximum spectral transmission and more importantly the power or pulse energy density for which the screen is tested. It should be noted however that since supervised screens are assumed, the duration of the test is only 100 s for a continuous wave laser.

4.6 CENELEC TC 76

According to the Dresden Agreement, in terms of technical work CENELEC's TC 76 is only active for projects which are not adopted by IEC's TC 76.

WG 1: LED measurement methods

WG 1 was set up when CENELEC TC 76 was required to have a solution to the issues relating to the over-classifications LEDs before March 1996. It is a shadow group, to be activated if there were a need for urgent action; however, to date it has not met.

WG 2: Incoherent sources

Similarily to WG 1, WG 2 was set up to shadow progress with WG 9 of IEC TC 76. WG 2 so far also has not met.

WG 3: *User guides for medical laser safety*

WG 3 was set up to review progress of the IEC TC 76 work on medical lasers. As the progress of the IEC Working Group 4 has been considered satisfactory, WG 3 has not been activated.

WG 4: Safety education and training

WG 4 is the only active working group of CENELEC TC 76. Currently this group is working on a document to specify minimal requirements regarding the syllabus for laser safety training, especially for the training of Laser Safety Officers. This project was offered to IEC according to the Dresden agreement; however, IEC TC 76 decided in 1995 that it does not want to pursue the project. The project is described in more detail in the following section.

4.7 LASER SAFETY TRAINING

WG 4 of CENELEC TC 76 is currently preparing a working group draft with the title: *„Guide to the Levels of Competence Required in Laser Safety"*.

This guide is to become a CEN/CENELEC report and its current scope is to provide information and guidance for the management of laser safety. As such it is to be understood as supplementary to EN 60825-1. It outlines the procedures for the management of laser hazards and establishes minimum levels of competence for those who work with laser equipment or who have responsibility for laser safety. It stresses that the employer is responsible to implement and maintain the necessary steps for the safe use of lasers and also for providing information and training for the employees. The Laser Safety Officer (LSO) acts on behalf of the employer and his role is described in more detail than in EN 60825-1. In the standard, only the *minimum* level of competence is described for the LSO and also for the users of lasers. For companies which only have a few lasers with a fixed installation, the LSO does not have to have the same level of competence necessary for a LSO in a research centre with numerous lasers with flexible set-ups. Companies also could make use of „Competent Advisors" who might not be employed by the company and whose role it is to suggest control measures for new installations. The subsequent role of the LSO in such a company would be to check the adherence to the control measure as suggested by the „Competent Advisor". This new role in managing laser safety in companies is also defined in the draft standard. In contrast to previous documents such as developed by International Working Group 4 of the EU 643 project, the working document described here does not contain a detailed syllabus, but rather describes procedures which the LSO and the laser user should understand or be able to perform.

5 ISO TC 172/SC 9, CEN TC 123

5.1 Scope and Working Groups

The subcommittee SC 9 of ISO/TC 172 „Electro-optical systems", adopted the following scope at its meeting in 1995:

> Standardisation of terminology, requirements, interfaces, test methods and test instruments for lasers, optical components intended for use with lasers as well as for laser accessories and laser-oriented equipment.
>
> Excluded are horizontal laser safety standards.
>
> Standardization of electro-optical systems is also included in the scope of SC 9 until that field is covered by a specific sub-committee of TC 172.

Insofar as it is related to laser standards, ISO/ TC 172 and CEN TC 123 have equivalent scopes.

In fact, by applying the rules of the Vienna Agreement for the cooperation between ISO and CEN, CEN/TC 123 decided at its last meeting in Glasgow to disband all its working groups, as the technical work was done by ISO/TC 172/SC 9. The editorial and managing work necessary for adoption of the laser standards on the European level is provided by the secretariat of CEN/TC 123.

The working groups of ISO/ TC 172/ SC9 are:

WG 1	Terminolgy and test methods for lasers
WG 2	Interfaces and system specifications for lasers
WG 3	Safety
WG 4	Laser systems for medical applications
WG 5	Laser systems for general applications
WG 6	Optical components and their test methods
WG 7	Electro-optical systems other than lasers

Working group 3 was active in the development of the standard on safety of laser materials processing, ISO 11553, and it is in the meantime joined with IEC/TC 76/WG 10. However, by agreement between the two working groups and committees, IEC/TC 76/WG 10 is the working group responsible for the maintenance of ISO 11553. Future projects in the field of industrial laser safety will be the responsibility of IEC/TC 76/WG 7, hence ISO/TC 172/SC 9/ WG 3 will most likely not be working on any projects of their own but rather contribute to work done by IEC TC 76 working groups.

5.2 Standards for Laser Parameters

A great deal of the work program of ISO/TC 172/SC 9 is covered by standard projects specifying test methods for laser beam parameters and optical components. These work items are backed up by the EUREKA project CHOCLAB (Characterisation of Optical Components and Laser Beams). It is the goal of this EUREKA project to support the scientific background for these standards, to evaluate their applicability and to improve their implementability in an industrial environment. Following the Vienna agreement, the draft standards are submitted to parallel voting and are published both as EN ISO and as ISO standards.

It has to be noted, that these standards do not apply to measurements intended for hazard classification of products or for measurements of irradiance and exposure to be compared to MPEs in the sense of IEC 825-1. The standards rather deal with the technical performance of laser products and with accurate ways of how to measure the corresponding parameters.

The standard specifying measurement of power, energy, and temporal characteristics, ISO/DIS 11554, contains requirements for the accuracy and performance of the measurment system, which are not necessary for safety related measurments, where the biological damage thresholds are not known with a comparable accuracy and limits vary from individual to individual.

However some issues covered in the ISO standards series are relevent for laser safety, such as the standard dealing with the assessment of the divergence angle (ISO/DIS 11146). The formula for the Nominal Ocular Hazard Distance (NOHD), as contained in IEC 825-1 assumes the beam diverges in a linear fashion from the exit window of the laser and does not account for possible beam waists outside of the laser cavity. Hence the formula as given in IEC 825-1 can grossly underestimate the possible extent of the NOHD- using the definitions and measurement techniques as contained in ISO/DIS 11146 for beam divergence, the calculation of the NOHD should be more realistic.

ISO/DIS 11146: Optics and optical instruments - Laser and laser related equipment - Test methods for laser beam parameters: *Beam widths, divergence angle and beam propagation factor.*

This international standard defines methods for determination of beam properties like beam diameter, divergence and beam propagation factor. These methods are not to be applied to strongly diffracted beams, e.g., those of unstable resonators.

ISO/DIS 11554: Optics and optical instruments - Lasers and laser-related equipment - Test methods for laser beam parameters: *Power, energy and temporal characteristics*

ISO/CD 13694: Optics and optical instruments - Lasers and laser-related equipment - Test methods for laser beam parameters: *Power (energy) density distribution.*

This International Standard specifies methods by which the measurement of a power (energy) density distribution is made and defines parameters for the characterization of the spatial properties of laser power (energy) density distribution functions at a given plane. The test methods given in this standard are intended to be used for testing and characterisation of both cw and pulsed laser beams.

ISO/DIS 11670: Optics and optical instruments - Laser and laser-related equipment - Test methods for laser beam parameters: *Beam positional stability*

This international standard defines methods for determination of the beam positional stabiltiy and is intended to be used for tests and characterising of lasers. This standard thus determines common basics for measuring this property. In addition, definitions of symbols and terms related to the beam positional stabiltiy are made.

ISO/DIS 12005: Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: *Polarization*

This international standard defines a relatively quick and simple method for determination of polarization and, if possible, the degree of polarization of a laser beam that requires a minimum of measuring equipment. This standard is applicable to cw-laser and pulsed laser beams as well.

5.3 ISO 11553, EN 12626

ISO 11553 „*Safety of machinery - Laser processing machines - Safety requirements*" was prepared by ISO/TC 172/SC 9, in collaboration with IEC/TC 76 and CEN/TC 123. In the meantime, the responsibility to maintain ISO 11553 rests with WG 10 of IEC/TC 76 which constitutes a joint working group with the experts of ISO/TC 172/SC 9/WG 9.

On the European level, the standard is published as EN 12626. Although the technical content of the two standards is equivalent, due the intention of EN 12626 to tie in with other European standards dealing with various aspects of machine safety, the text has not been published as EN ISO 11553 but as an indigenous European standard. The main difference however, between the ISO and the EN version, is that EN 12626 references and correlates to specific EN standards which do not exist on the international level.

EN 12626 is a standard of type B as defined in EN 414, and should give support to authors of type C-standards. The corresponding standard of type A is EN 292 „*Safety of machinery*" which is mandated by the Directive on machinery.

In the following, the contents of EN 12626 will be briefly reviewed, however the discussion is also applicable to ISO 11553.

EN 12626 describes hazards generated by laser processing machines and specifies the safety requirements relating to hazards caused by radiation as well as hazards generated by materials and substances. It also specifies the information to be supplied by manufacturers of such equipment. It is not applicable to laser products that are manufactured solely and expressely for the following applications:

photolithography, stereolithography, holography, medical applications and data storage.

The purpose of the standard is to avoid injuries by

- making a list of possible risks
- defining safety steps and safety tests
- providing information on relevant standards
- specifying information which is to be passed to the user

These points reflect the application of the principle of risk assessment, as intended by the Directive on machinery.

EN 12626 places emphasis on the duty of the manufacturer to supply the user with information:

- The manufacturer shall supply pertinent safety-related documentation about the hazards of dust and fumes generated by laser material processing. The minimum requirements are knowledge of possible by-products, determination of health risks, and necessary precautions, including information

  a) about the responsibilities of the user relating to the removal of fumes and particulate material from the machine

  b) on the limit values for the materials intended to be processed and for the fumes and particulate matter generated by machining these materials.

- The manufacturer shall supply pertinent safety- related documentation about design of adequate measures to avoid hazards (especially exhaust systems for fumes and dust)
- The manufacturer shall make available suitable safety-related training to the user (information, instruction and training of operators)
- The manufacuter shall advise users of known potential hazards by providing a prominently placed warning statement in the user instructions and/or operator´s manual.

6 NON-RADIATION STANDARDS

Standards which are relevant for the safe design and use of lasers for materials processing but which are not directly related to laser radiation are reviewed in the following sections.

6.1 MACHINE SAFETY

The essential health and safety requirements of the machinery Directive comprise specifications for:

- general principles to achieve safety
- controls
- protection against mechanical hazards
- guards and protection devices
- protection against other hazards, e.g., electricity, fire, etc. In this clause laser radiation is specifically mentioned and the following provisions are taken into account:
- prevention of accidental radiation
- protection against effective, reflected, diffused and secondary radiation
- safety of optical equipment for observation or adjustment
- maintenance
- indicators

The standard of type A corresponding to the Directive on machinery is EN 292: „*Safety of machinery- Basic concepts, general principles of design*"

This standard was published in two parts:

Part 1: Basic terminology, methodology

Part 2: Technical principles and specifications

As standard of type A, EN 292 specifies fundamental safety related requirements which are applicable to all machines.

In the field of laser safety, the applicable standard of type B is EN 12626 „*Safety of machinery - Laser processing machines - Safety requirements*".

6.2 AIR CONTAMINANTS

EN 12626 as mentioned above establishes the duty of the manufacturer to inform the user about potential hazards generated by materials and substances whereas the safe removal and disposal of fumes and particulate matter from the machine according to local, national or regional Threshold Limit Values are the responsibility of the customer. Some additional standards related to air contaminants and relevant for laser materials processing are listed below:

EN 626-1: *Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery - Part 1: Principles and specifications for machinery manufacturers*

The document specifies principles which shall be observed during the construction of machines in order to reduce the risk to health by hazardous substance emitted by the machine.

EN 626-2: *Safety of machinery - Reduction of risk to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures*

The document defines a procedure which leads to the selection of relevant factors relating to emissions of hazardous substances for the purpose of suitable verification parameters. It also provides type C standard writers with guidance to enable the development of procedures relating to verification. Such procedures are required to take account of the health risks asociated with the emission of hazardous substances at all stages in the life of a machine.

EN 481: *Workplace atmospheres; size fraction definitions for measurement of airborne particles.*

The document defines the inspirable and respirable fractions of the dust at the workplace

EN 482: *Workplace atmospheres - General requirements for the performance of procedures for the measurement of chemical agents.*

6.3 Eye Protection

Two standards have been developed by CEN/ TC 85 which deal with the requirements for testing of laser eye protection:

EN 207 *„Personal eye-protection. Filters and eye-protection against laser radiation"*

EN 208 *„Personal eye-protection. Eye protectors for adjustment work on lasers and laser systems"*

The scope of these standards is to specify requirements, test methods and labeling of personal laser eye-protection. EN 207 applies to regular laser eye-protection for which it is not necessary to be able to see the laser beam. EN 208 has been developed for laser adjustment eye-protectors, which reduce the beam to levels below the MPE, but which still permit the beam to be seen so that adjustments can be performed.

The philosophy behind the standards is, that it is not only sufficient for an eye-protector to absorb the laser radiation, i.e. to exhibit a high optical density for the wavelength of the respective laser radiation which reduces the radiation to below the MPE. It is of equal importance, that the filter can actually withstand the level of irradiance or exposure for which it is intended. For example, almost every material is practically opaque for the wavelength of CO_2 laser radiation - even an overhead transparency. However, obviously the transparency would not withstand the laser radiation against which a laser eye-protector typically has to protect. The standard EN 207 therefore specifies protection levels and corresponding irradiance levels (power densities) and exposure levels (energy densities), which are used to test the eye-protector (the filter and the frame) for 10 seconds. For a given protection level, say L3 at a wavelength of 10,6 μm, it is guaranteed that the filter has an optical density of at least the value of the protection level, and that the eye-protector also can withstand, for this example, 10^6 W/m^2 of CO_2 laser radiation for at least 10 seconds.

EN 208 for laser adjustment eye-protectors specifies similar protection levels, however the optical density and the corresponding protection level is to be chosen such that the filter reduces the level of the visible laser radiation to 1 mW, which is the AEL for Class 2.

7 The American Scene

There are several important differences between American laser safety standards and their applications and the European system. The main difference is that the American system relies on a specific mandatory standard for manufacturers as published by a governmental agency and a standard containing guidance information for users as published the American National Standards Institute. Neither of the standards are completely equivalent to the international standard IEC 825-1; however, during recent years there were several initiatives on the USA side to harmonise their standards with the respective international standards. Also since products exported to the European Union must comply with the applicable Directives and the related European Standards, the interest of the USA in international and European standardisation has increased.

This section briefly points out the pertinent characteristics of american standards relevant to laser safety, and in particular to materials processing, where an ANSI guidance standard, B11.21, is also close to being published.

7.1 CDRH Requirments

In the USA, the regulatory requirements for laser product manufacturers are defined by the CDRH *(Center for Devices and Radiological Health),* which is part of the *FDA (Food and Drug Administration).* The standard currently applicable is *The Federal Laser Products Performance Standard* (21 CFR 1040.10 and 1040.11). The requirements are in many cases equivalent to the manufacturers' requirement as specified in IEC 825-1, however some differences exist, for example in regards to classification requirements and labeling. In contrast to IEC 825-1, the CDRH standard denotes the hazard classes with roman numerals and also defines a hazard Class IIa. As the FDA is part of the U.S. Department of Health and Human Services, the requirements have a mandatory legal character, and every manufacturer of laser products is required to report their laser product and the classification details to the CDRH. The CDRH in turn checks the report for plausibility and can decide to investigate in more detail.

7.2 ANSI Z136 Series

The ANSI *(American National Standards Institute)* is the United States member of the ISO and IEC. The American National Standard ANSI Z136-series is the series of standards concerned with laser safety.

It should be noted that ANSI did not adopt the international standard IEC 825-1 as the american national laser safety standard. ANSI Z136.1 is rather a guidance standard for the safe use of lasers. The technical content of ANSI Z136.1 is similar to the section on user guidance of IEC 825-1, but differences exist. The classification scheme used by ANSI is equivalent but not identical to the CDRH classification scheme. Hazard classes are denoted with arabic numerals and subclasses have lower case letters, such as Class 2a, which distinguishes it from the IEC 825-1 class denomination. As such, the standard is not mandatory, but state governments can choose to reference it in their state -laws.

Specific ANSI standards have also been published for fiber communication systems, Z136.2-1988 and for lasers in medical applications Z136.3-1996. ANSI standards on measurement, Z136.4, outdoor use, Z136.6, and use in educational institutions, Z136.5, are under development. Each of these is based on the primary standard, Z136.1-1995.

7.3 ANSI B11.21

Title: *American National Standard for Machine Tools - Machine Tools Using Lasers for Processing Materials - Safety Requirements for Design, Construction, Care and Use*

This standard is part of the ANSI B11 series (*Safety standard machine tools*) and pertains to the safety requirements for lasers used in machine tool applications. At the time of this writing, the standard is in the final draft status and is soon to be published.

From the European perspective it is interesting to note the format of the standard which consists of two columns: the text of the actual standard is contained in the left column, while explanatory information has been placed in the right column, adjacent to the applicable requirements. The explanatory information also includes information which is pertinent to „European compliance", specifying relevent standards throughout the text.

The standard applies to machine tools using laser radiation to process materials. It describes the hazards generated by such machines and states the safety measures to be incorporated into such machines. At this point it should be mentioned that the ANSI definition of a laser processing machine differs slightly from the European definition of a complete machine per EN 292-1.

The purpose of this standard is to establish safety requirements with respect to the design, construction, safeguarding, care and use of machine tools using lasers. A second purpose of this standard is to assign safety responsibilities for both the supplier and user, respectively. The requirements of this ANSI standard are grouped according to those that apply to the supplier and user, with some requirements common to both the supplier and user. The structure and relationships of these requirements are schematically depicted below.

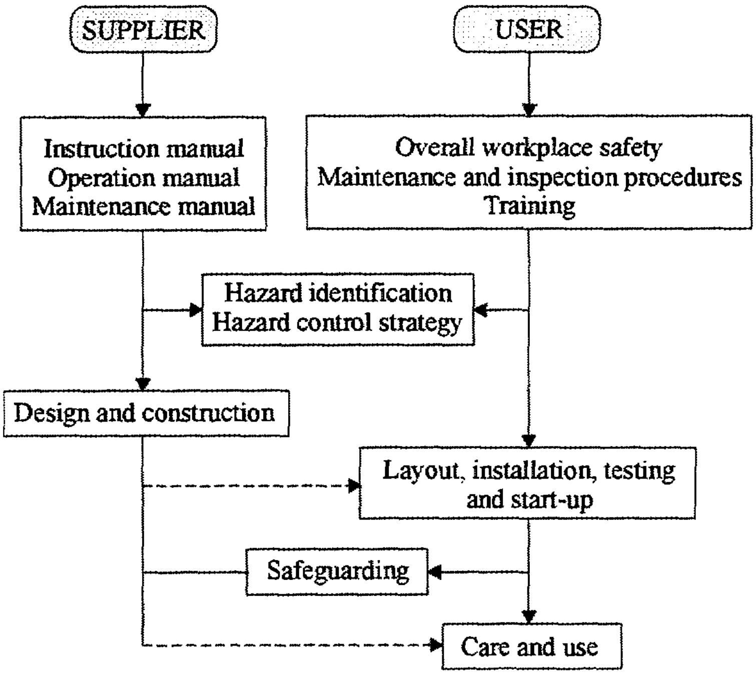

Fig. 5 Responsibilities of laser supplier and user

8 ACKNOWLEDGEMENTS

The report was supported in the framework of the EuroLaser UETP project „Safety in the Industrial Applications of Lasers“.

The author is grateful for the contribution of Dr. Georg Vees in preparing the list of standards and for the collation of material for the sections on American Standards, Laser Parameters, Safety of Machinery and Air Contaminants.

Valuable information has been received by the following individuals, which is gratefully acknowledged: Michael Green (PROLASER), Roy Henderson (bioptica), David Sliney (US Army), Jim Smith (Rockwell Laser Industries), Ernst Sutter (PTB), and Bryan Tozer (Lasermet).

The author would like to thank Prof. Darrell Seeley (Milwaukee School of Engineering) for providing valuable suggestions for improvement in terms of style and structure.

9 FURTHER READING

D. Sliney, M. Wolbarsht *Safety with Lasers and Other Optical Sources*, Plenum Press NY 1980

R. Henderson, A Guide to Laser Safety, Chapman & Hall, London 1997

ICNIRP *Guidelines on Limits of Exposure to Laser Radiation of Wavelengths Between 180 nm and 1,000 μm*, Health Physics, Volume 71, pages 804 - 819.

ACGIH, *TLVs and BEIs „Lasers"*, Cincinatti 1996

A list of papers related to international standardistation is produced below from the contents of :

Proceeding of the ILSC 1990, 1992 and 1997. The Proceedings can be obtained from

Laser Institute of America, 12424 Research Parkway, Suite 125, Orlando FL 32826

email <dparzych@mail.creol.ucf.edu>

1990 International Laser Safety Conference

1992 International Laser Safety Conference

1997 International Laser Safety Conference

Session 1: Plenary Session

Session 2: Safety Standards

10 APPENDIX: LIST OF STANDARDS

by Georg Vees and Karl Schulmeister

This appendix lists standards which are relevant for the safe use of lasers and also for the application of lasers in materials processing. The appendix is organised according to the standards organisation which published the standard:

- ISO
- IEC
- EN

Languages are English and French for ISO and IEC documents and English, French and German for EN documents, if not otherwise specified

In the sections of ISO and EN, the list of standards are themselves divided into the sub-sections according to groups of general (safety) standards, and into standards related to „Machine-Safety and Air Contaminants".

IEC

Document	**IEC 76/159/FDIS**	1996-04-00
Title	IEC 60825-4: Safety of laser products - Part 4: Laser guards	
Comments	Final Draft International Standard.	

Document	**IEC 76/142/CDV**	1996-04-00
Title	Amendment 1 to IEC 60825-2: Application notes for the safe use of optical fibre communications systems	
Comments	Draft for Vote. At the time of this writing (Aug 97), the CDV was accepted to be published as an FDIS.	

Document	**IEC 76/155/CDV**	1996-04-00
Title	Amendment to IEC 60825-1: Symbols to be used as alternatives to the wording od laser safety labels	
Comments	Draft for Vote.	

Document	**IEC 76/157/FDIS**	1997-04-25
Title	Amendment 1 to IEC 60825-1	
Comments	Final Draft International Standard. At the time of writing (August 97), the Amendment was accepted for publication. IEC 60825-1/A1:1997 is not identical with EN 60825-1/A11:1996 but technically equivalent.	

Document	**IEC 76/160/CDV**	1997-06-13
Title	Technical Report Type 3: IEC 60825-5. Safety of laser products, Part 5: Manufacturer's checklist for IEC 60825-1	
Comments	Draft for Voting. Guidance note in addition to IEC 60825-.1	

Document	**IEC 601-2-22**	1995-11-00
Title	Medical electrical equipment - Part 2: Particular requirements for the safety of diagnostic and therapeutic laser equipment	
Abstract	Object is to specify particular requirements for the safety of laser equipment for medical applications classified as a class 3B or class 4 laser product.	
Comments	---	

Document	**IEC 825-1**	1993-11-00
Title	Safety of laser products; part 1: equipment classification, requirements and user's guide	
Abstract	Specifies minimum safety requirements for laser products and is divided into three sections: general, manufacturing requirements, user's guide. Laser products which are sold to other manufacturers for use as components of any system for subsequent sale are not subject to IEC 825-1, since the final productwill itself be subject to this standard. Light emitting diodes are included whenever the word "laser" is used. The object is to protect persons from laser radiation in the wavelength range 180 nm to 1 mm as well as against other hazards resulting from the operation and use of laser products.	
Comments	Amendment 1 has been accepted to be published in August 1997. Following a new policy, the amendment will be published as such and a consolidated version IEC 60825-1 + A1 will also be available.	

Document	**IEC 825-2**	1993-09-00
Title	Safety of laser products; part 2: safety of optical fibre communication systems	
Abstract	Provides requirements and specific guidance for the safe use of optical fibre and/or control communication systems where optical power may be accessible at great distance from the optical source. Light emitting diodes are included whenever the word "laser" is used. The objective is to protect people from optical radiation, lay down requirements for manufacturers and operatingorganizations, ensure adequate warning to individuals of hazards associated with optical fibre communication systems, reduce the possibility of injury by minimising unnecessary accessible radiation.	
Comments	---	

Document	**IEC/TR 825-3**	1995-12-00
Title	Safety of laser products - Part 3: Guidance for laser displays and shows	
Abstract	Gives guidance on the planning and design, set-up and conduct of laser displays and shows that use of high power lasers. Is not intended to include the display or demonstration of scientific, medical and industrial laser products at trade shows, etc. Provides recommendations for safety for those laser displays or demonstrations that are shows, artisticdisplays or light sculptures or museum pieces used to demonstrate optical principles, etc.	
Comments	Guidance. No equivalent CEN/CENELEC Report has been published	

Document	**IEC 1040**	1990-12-00
Title	Power and energy measuring detectors, instruments and equipment for laser radiation	
Abstract	States definitions, minimum requirements, and appropriate test methods for the characteristics and manufacturing standards.	
Comments	---	

ISO

Document	**ISO 6161**	1981-02-00
Title	Personal eye-protectors; Filters and eye-protectors against laser radiation	
Abstract	Specifies requirements for spectacle filters and protectors within the spectral region 0,2 to 1000 micron. The work, which was staggered over several years, represents a basic study for which a majority consensus was reached at the international level. To take account of new developments and knowledge relating to lasers a revision of this standard will be undertaken.	
Comments	This standard is obsolete, however further work is not persued by ISO. EN 207 is to be applied on the European level.	

Document	**ISO 11553**	1996-09-00
Title	Safety of machinery - Laser processing machines - Safety requirements	
Abstract	Describes hazards generated by laser processing machines and specifies the safety requirements to avoid hazards caused by radiation.	
Comments	equivalent to EN 12626	

Document	**ISO/FDIS 11149**	1996-12-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Fibre optic connectors for non-telecommunication laser applications	
Comments	Draft International Standard	

Document	**ISO/DIS 11151-1**	1993-06-00
Title	Optics and optical instruments; lasers and laser related equipment; standard optical components; part 1: components for the UV, visible and near-infrared spectral range	
Comments	Draft International Standard	

Document	**ISO 11253**	1993-09-00
Title	Lasers and laser related equipment; laser device; mechanical interfaces	
Abstract	Specifies dimensions of mounting-hole patterns for attaching external devices to a laser device around the beam.	
Comments	---	

Document	**ISO 11145**	1994-11-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Vocabulary and symbols	
Abstract	Defines basic terms, symbols and units of measurement for the field of laser technology in order to unify the terminology and to arrive at clear definitions and reproducible tests of beam parameters and laser-oriented product properties.	
Comments	—	

Document	**ISO/DIS 11146**	1995-11-00
Title	Optics and optical instruments - Laser and laser related equipment - Test methods for laser beam parameters: Beam widths, divergence angle and beam propagation factor	
Comments	Draft International Standard	

Document	**ISO/DIS 11254**	1991-09-00
Title	Optics and optical instruments; lasers and laser related equipment; test methods for laser induced damage threshold of optical surfaces	
Comments	Draft International Standard	

Document	**ISO/FDIS 11551**	1997-01-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Test method for absorptance of optical laser components	
Comments	Final Draft International Standard	

Document	**ISO/DIS 11554**	1995-04-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Test methods for laser beam parameters: Power, energy and temporal characteristics	
Comments	Draft International Standard	

Document	**ISO/DIS 11670**	1995-11-00
Title	Optics and optical instruments - Laser and laser-related equipment - Test methods for laser beam parameters: Beam positional stability	
Comments	Draft International Standard	

Document	**ISO/DIS 12005**	1995-04-00
Title	Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: Polarization	
Comments	Draft International Standard	

Document	**ISO 11252**	1993-09-00
Title	Lasers and laser-related equipment; laser device; minimum requirements for documentation	
Abstract	Specifies the minimum documentation and marking and labelling information requirements to be provided with laser devices. The documentation is presented on two levels: as a technical data sheet and as an instruction manual. Does not apply to laser products which incorporate laser devices.	
Comments	—	

ISO *Machine-Safety, Air Contaminants*

Document	**ISO/DIS 10882-1**	1997-01-00
Title	Health and safety in welding and allied processes - Sampling of airborne particles and gases in the operator's breathing zone - Part 1: Sampling of airborne particles	
Comments	Draft International Standard	

Document	**ISO/DIS 10882-2**	1995-07-00
Title	Health and safety in welding and allied processes - Sampling of airborne particles and gases in the operator's breathing zone - Part 2: Sampling of gases	
Comments	Draft International Standard	

Document	**ISO/TR 12100-1**	1992-12-00
Title	Safety of machinery; basic concepts, general principles for design; part 1: basic terminology, methodology	
Abstract	The document defines basic terminology and specifies general design methods, to help designers and manufacturers in achieving safety in the design of machinery for professional and non-professional purposes.	
Comments	Technical Report	

Document	**ISO/TR 12100-2**	1992-12-00
Title	Safety of machinery; basic concepts, general principles for design; part 2: technical principles and specifications	
Abstract	The document defines technical principles and specifications to help designers and manufacturers in achieving safety in the design of machinery for professional and non-professional purposes. It may also be used for other technical products having similar hazards.	
Comments	Technical Report	

Document	**ISO 13850**	1996-11-00
Title	Safety of machinery - Emergency stop - Principles for design	
Abstract	Specifies functional requirements and design principles for the emergency stop of machinery, independent of the type of energy used to control the function.	
Comments	—	

Document	**ISO/DIS 14123-1**	1996-10-00
Title	Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery - Part 1: Principles and specifications for machinery manufacturers	
Comments	Draft International Standard	

Document	ISO/DIS 14123-2	1996-10-00
Title	Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification procedures	
Comments	Draft International Standard	

EN

Document	**EN 207**	1993-10-00
Title	Personal eye-protection - Filters and eye-protection against laser radiation	
Comments	---	

Document	**EN 208**	1993-10-00
Title	Personal eye-protection; eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)	
Comments	---	

Document	**prEN 12254**	1995-11-00
Title	Screens for laser working places - Safety requirements and testing	
Comments	Draft. To be included into IEC 60825-4 (Guards) as Appendix.	

Document	**EN 12626**	1997-02-00
Title	Safety of machinery - Laser processing machines - Safety requirements (ISO 11553:1996 modified)	
Comments	equivalent to ISO 11553 with minor differencies resulting from quoting,European standards which do not have ISO eqivalents.	

Document	**EN 60601-2-22**	1996-01-00
Title	Medical electrical equipment - Part 2: Particular requirements for the safety of diagnostic and therapeutic laser equipment (IEC 601-2-22:1995)	
Comments	---	

Document	**EN 60825-1 + A11**	1997-03-00
Title	Safety of laser products; part 1: equipment classification, requirements and user's guide	
Abstract	see IEC 825-1	
Comments	EN 60825-1:1994 + A11:1996 is technically equivalent to IEC 825-1:1993 + A1:1997, however due to the different wording of the amendments is not identical to it.	

Document	**EN 60825-2**	1994-01-00
Title	Safety of laser products; part 2: safety of optical fibre communication systems (IEC 825-2:1993)	
Comments	---	

Document	**prEN 31151-1**	1993-06-00
Title	Optics and optical instruments; lasers and laser related equipment; standard optical components; part 1: components for the UV, visible and near-infrared spectral range	
Comments	Draft	

Document	**EN 31253**	1994-04-00
Title	Lasers and laser-related equipment - Laser device - Mechanical interfaces (ISO 11253:1993)	
Comments	---	

Document	**prEN ISO 11149**	1996-12-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Fibre optic connectors for non-telecommunication laser applications (ISO/DIS 11149:1996)	
Comments	Draft	

Document	**prEN ISO 11551**	19997-01-00
Title	Optics and optical instruments - Lasers and laser-related equipment - Test method for absorptance of optical laser components (ISO/DIS 11551:1997)	
Comments	Draft	

Document	**EN 61040**	1992-10-00
Title	Power and energy measuring detectors, instruments and equipment for laser radiation (IEC 1040:1990)	
Comments	---	

Document	**EN ISO 11145**	1994-11-00
Title	Optics and optical instruments - Lasers and laser related equipment - Vocabulary and symbols (ISO 11145:1994)	
Abstract	The document defines terms , symbols and units of measures for the field of laser technology in order to unify the terminology and to come to clear definitions and reproducible tests of beam parameters and laser-oriented product properties.	
Comments	---	

Document	**prEN ISO 11146**	1995-11-00
Title	Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: Beam widths, divergence angle and beam propagation factor (ISO/DIS 11146:1995)	
Comments	Draft	

Document	prEN ISO 11554	1995-04-00
Title	Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: Power, energy and temporal characteristics (ISO/DIS 11554:1995)	
Comments	Draft	

Document	prEN ISO 11670	1995-11-00
Title	Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: Beam positional stability (ISO/DIS 11670:1995)	
Comments	Draft	

Document	prEN ISO 12005	1995-04-00
Title	Optics and optical instruments - Lasers and laser related equipment - Test methods for laser beam parameters: Polarization (ISO/DIS 12005:1995)	
Comments	Draft	

Document	EN 31252	1994-04-00
Title	Lasers and laser-related equipment - Laser device - Minimum requirements for documentation (ISO 11252:1993)	
Comments	—	

EN *Machine-Safety, Air Contaminants*

Document	EN 292-1	1991-09-00
Title	Safety of machinery; basic concepts, general principles for design; part 1: basic terminology, methodology	
Comments	—	

Document	EN 292-2	1991-09-00
Title	Safety of machinery; basic concepts, general principles for design; part 2: technical principles and specifications	
Comments	—	

Document	EN 292-2/A1	1995-03-00
Title	Safety of machinery - Basic concepts, general principles for design - Part 2: Technical principles and specifications; Amendment A1	
Comments	—	

Document	EN 481	1993-07-00
Title	Workplace atmospheres; size fraction definitions for measurement of airborne particles	
Comments	—	

Document	EN 482	1994-07-00
Title	Workplace atmospheres - General requirements for the performance of procedures for the measurement of chemical agents	
Comments	—	

Document	EN 626-1	1994-09-00
Title	Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery - Part 1: Principles and specifications for machinery manufacturers	
Comments	—	

Document	EN 626-2	1996-07-00
Title	Safety of machinery - Reduction of risk to health from hazardous substances emitted by machinery - Part 2: Methodology leading to verification	
Comments	—	

Document	**EN 838**	1995-11-00
Title	Workplace atmospheres - Diffusive samplers for the determination of gases and vapours - Requirements and test methods	
Comments	---	

Document	**EN 842**	1996-06-00
Title	Safety of machinery - Visual danger signals - General requirements, design and testing	
Comments	---	

Document	**prEN 60204-X**	1994-05-00
Title	Safety of machinery; electrical equipment of machines; part X: general requirements for high voltage equipment for voltages up to 36 kV	
Comments	Draft	

Document	**EN 60204-1**	1992-10-00
Title	Safety of machinery; electrical equipment of machines; part 1: general requirements (IEC 204-1:1992, modified)	
Comments	---	

Document	**EN 61310-1**	1995-03-00
Title	Safety of machinery - Indication, marking and actuation - Part 1: Requirements for visual, auditory and tactile signals (IEC 1310-1:1995)	
Comments	---	

Document	**EN 61310-2**	1995-03-00
Title	Safety of machinery - Indication, marking and actuation - Part 2: Requirements for marking (IEC 1310-2:1995)	
Comments	---	

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