LA-UR-85-3834

CONF-851087--41

LA-UR--85-3834

DE86 002430

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TITLE: WORKSHOP ON STANDARDS FOR PHOTONIC STREAK CAMERA CHARACTERIZATION

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SUBMITTED TO: SPIE's 29th Annual Technical Symposium
Town & Country Hotel
San Diego, California

August 19-23, 1985

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

FORM NO 836 R4
ST NO 2629 5/81

Workshop on standards for photonic streak camera characterization

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Introduction

A summary paper* proposing standardization of definitions and parameter measurements related to photonic streak cameras was generated at the 16th International Congress of High Speed Photography and Photonics at Strasborg, France (August 1984). An international committee appointed by the general Workshop on Picosecond Streak Cameras met and discussed the areas appropriate for standardization and proposed specific definitions, measurements and complementary parameter sets to be used in characterizing photonic streak cameras. These proposals were compiled into a summary paper by the committee co-chairmen, Noel Fleurot (CEA-Limeil) and Gary L. Stradling (Los Alamos National Laboratory), with the intent that it be distributed to interested streak camera users and manufacturers and that appropriate improvements and additions be solicited.

The purpose of this workshop was to discuss the proposals of the Strasborg committee and to obtain comment from the local U.S. streak camera community. There were 40-50 participants in attendance. This workshop began with a presentation of the Strasborg summary paper by the chairman, including some explanation of the motivation and intent of the proposals. This presentation was followed by comment from a number of the participants in which a variety of issues were brought forward. These issues were discussed in the Workshop. The participants generally agreed that several suggestions be carried back to the international committee for implementation in the Strasborg standards proposal.

A summary** is made below of the discussion and conclusions which followed the presentation of the Strasborg standardization criteria to the workshop.

Paul Jaanamagi (Lawrence Berkely Laboratory)

- Vacuum level requirements should be specified for x-ray streak cameras by manufacturers.
- Image processing is being used to enhance performance characteristics of streak cameras. These techniques should be taken into account when defining standard measurements.
- Dynamic range measurements depend on pulse width and should be made at a sweep speed matched to the pulse width being measured.

George Kyrala (Los Alamos National Laboratory)

- For those who assemble their own streak systems, individual components should be characterized separately.
- Operating voltages should be specified for optimum performance of each unit.
- Performance characteristics of a given design vary between different units. Thus characterization of a single unit may not be fully representative of all units of a given model.
- Base sensitivity of streak cameras should be measured. The base level should correspond to a doubling of the noise level.
- Modulation of 20% between two pulses is acceptable as a standard for time resolution measurements.

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*Workshop on Picosecond streak cameras by Noel Fleurot and Gary L. Stradling, Proceedings 16th Annual International Congress on High Speed Photography and Photonics, Strasborg, France, Aug 1984.

**The workshop discussion required extensive abridgment and editing for inclusion in this report. The chairman has attempted to accurately summarize the main points put forth by the various participants. If further detail is required, a verbatim transcript is available.

- Jitter and drift in the internal sweep timing should be specified by manufacturers as well as the warm-up time necessary to obtain the quoted performance.

- Temporal and spatial resolution should be given in terms of the total number of resolution elements available with the particular instrument.

Barry Nye (Sandia National Laboratory)

- Spatial resolution characterization should be geared toward applications which use multiple fiber optic channel inputs, in which good channel-to-channel isolation is required.

- Both complete systems and individual tubes should be characterized.

- Single shot measurements are quite different from cumulative measurements over many shots. Characterizations should be based on single shot measurements.

- Instrument systems of a given model should have interchangeable components.

Charles McMillan (Lawrence Livermore National Laboratory)

- High precision velocimetry is accomplished at LLNL with a Fabry-Perot interferometer and using a streak camera to detect time dependent shifts in fringe patterns. This technique requires high temporal and spatial fidelity (0.5%).

- Specification of only "limiting dynamic spatial resolution" is inadequate and misleading. This parameter is limited to the modulation value corresponding to a single spatial frequency which is only one point on a modulation transfer function (MTF) curve. For example, MTF curves of dramatically differing low frequency features can all pass through a 5% modulation point at 20 lp/mm.

- Temporal resolution and spatial resolution are not always orthogonal parameters. There is some interdependence between them. This is apparent in very precise measurements.

- Geometric distortion should be carefully characterized by manufacturers.

- Sweep rates are not always uniform across the spatial extent of the photocathode resulting in a slight "rotation" of the slit. With time, this small effect is critical for precise measurements.

Keith Hindricks (EGG/San Ramon)

- Characterization needs of different users vary. We should avoid trying to satisfy all needs of all streak camera users but instead limit parameterizations to finite set of general interest. The Strasborg committee did a good job of coming up with such a set.

- The dynamic range limit of 20% broadening is meaningful to a large body of streak tube users.

- Of course, the sweep speed will affect the dynamic range measurement and must be specified.

- Temporal resolution measurement should be based on the modulation between two very short, closely spaced pulses.

- Static resolution measurements are adequate for use with sweep windows of several hundred nanoseconds. The electron transit time through the deflection system is small compared to the total sweep time. However, unbalanced deflection plates can generate astigmatism in the image even at slow sweep speeds.

Ching Lai (Lawrence Livermore National Laboratory)

- In giving temporal resolution, either impulse broadening or two pulse modulation measurements are okay. However, it is important to address current density inside the tube as this affects the temporal resolution by even a factor of 10. The flux density on the photocathode, the photocathode sensitivity and the wavelength used for the measurement should be given.

Paul Weiss (Los Alamos National Laboratory)

- Tube loading affects resolution, dynamic range, and geometric distortion. At the photocathode both photocathode current and space charge affect tube performance and at the electron lens cross over region space charge also affects tube performance. I do not have a proposal for how these performance limitations should be specified.

- The attendance at this meeting indicates the level of interest in the performance specification issue. While these instruments are not simple oscilloscopes, we should notice that Tektronix requires a full catalog page to specify an oscilloscope without plugins. We are considering replacing 50 oscilloscopes with one instrument. Complete specification of streak tubes is impractical and very expensive, but we can make a basic set of measurements which form a basis of comparison between different instruments.

- Performance parameters vary depending on the image position along the photocathode and the sweep.

Gary Stradling, Chairman (Los Alamos National Laboratory)

As other have commented, we cannot responsibly include criteria which are uniquely limited to specific experiments. It is interesting, though, to hear the variety of applications for which streak cameras are being used.

This meeting should agree as to the criteria presented here which are general enough to be submitted to the International community for inclusion in the Strasborg standardization criteria.

Various criteria were put to a vote and the meeting agreed to the following submissions to the standardization committee:

- Pulse width and sweep speed used in dynamic range measurements should be given when specifying dynamic range characteristics.

- Vacuum operating levels required for x-ray streak cameras to obtain quoted performance should be specified by manufacturers.

- Jitter and drift of sweep timing with respect to the trigger and the warm-up time required to obtain the quoted performance should be specified by the manufacturer.

- This group needs parameterization measurements to be performed in the single-shot mode. However, there are also applications to which multiple scans are relevant. Measurement data should specify whether single shot or multiple scans were used.

- Modulation transfer function curves should be provided as completely as possible. This statement strongly supports the Strasborg criteria. Users should extend their measurement results and facilities to instrument manufacturers as far as is reasonable in order to establish these characteristics.

The topic of selecting an appropriate base level for dynamic range measurements was debated at length. General agreement on a definition was not obtained, however.

Some points brought out in this discussion include:

- For some applications, a base level detectivity may be defined as the amount of signal required to double the system noise level.

  However, the readout devices are often the dominant source of noise as well as being a limitation on the saturation level.

- The noise level of the system depends on the size of the fundamental resolution element or pixel over which the noise is integrated.

- Particularly at the highest sweep rates, the data is often limited to a scattering of detected photons. Evaluation of temporal or spatial features under these statistical conditions is very difficult.

The Strasborg committee co-chairmen have met and included these suggestions from the San Diego SPIE workshop into the earlier summary. A revised proposal for standardization criteria concludes this report. Changes and additions are shown in bold face type.

STANDARDIZATION CRITERIA FOR PHOTONIC STREAK CAMERA CHARACTERIZATION

1. Dynamic range and intensity transfer function:

The dynamic range at a given pulse width is measured by using intensity calibrated input pulses. A 20% temporal broadening of the pulse, due to increased photon flux, and measured at FWHM intensity is taken to be the limit of operation. The dynamic range is then the ratio of input photon flux, corresponding to 20% broadening, to that corresponding to the photon flux threshold for clear resolution of the temporal pulse. Definition of threshold level should be given.

Complementary parameters which should be specified are:

Input flux density on the photocathode (absolute values: Joules/cm²...)
Spatial dimension of pixel used for measurement
Wavelength
Sweep Speed
Single shot or multiple sweep measurement should be indicated

2. Spatial resolution:

To specify spatial resolution only in the static mode is not appropriate for streak cameras.

Spatial resolution ought to be specified in the dynamic mode as MTF or CTF curves as completely as possible. Complementary parameters which should also be given include:

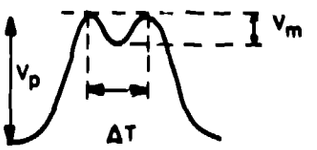
- sweep speed
- width of static slit image in sweep direction
- wavelength
- flux level
- sample size in sweep direction for dynamic measurement
- **single shot or multiple sweep measurement should be indicated.**

Information concerning degradation of spatial resolution off axis should be given.

3. Temporal resolution:

Temporal resolution should be specified by one of the two following criteria:

- FWHM of the pulse response to a delta intensity input function
- or by Rayleigh limit ΔT such that the contrast
  C = Vm/Vp = 20%



The following complementary parameters should be simultaneously specified:

- sample width in spatial direction
- sweep speed
- flux density level
- wavelength
- spatial resolution corresponding to this temporal resolution
- **single shot or multiple sweep measurement should be indicated**

Information concerning degradation of temporal resolution off center should be given.

4. Sweep speed linearity:

A linearity curve should be given for characteristic sweep speeds of the system, the curve should be defined over the entire sweep window.

5. Geometric distortions:

Geometric distortions should be shown as a pictorial image, or analytically specified in dynamic mode:

- over entire sweep window
- for a given flux density
- wavelength should be specified
- sweep speed should be specified.

6. Intensity uniformity:

A description of non-uniformities should be given for photocathode, phosphor, intensifier, or preferably for the complete system. Pictorial representations or graphs are useful.

7. Photocathode:

- Useful size for streak operation of the system should be stated.
- Spectral sensitivity should be given (radiometric units).

8. Vacuum requirements:

The vacuum operating levels of x-ray streak cameras which are required to obtain quoted performance should be specified.

9. Timing stability:

Jitter and drift of sweep timing with respect to the trigger and the warm-up time required to obtain the quoted performance should be specified by the manufacturer.

10. Operating voltages:

Tube voltages required for optimum performance should be supplied with each unit.

The group of users recommends and encourages manufacturers to describe as completely as possible the parameters which effect a quoted measurement; recommendations of what constitutes compelteness is given in our description of each measurement.

Users should be advised of possible issues that could influence the response of the system (ex: changes in photocathode sensitivity, etc...) and should be given information to facilitate the control of such response variations.

Recognizing that facilities required to measure these parameters are in some cases specialized and difficult to access by manufacturers, we recommend that photonic streak camera users extend themselves and their test facilities to assist manufacturers in obtaining the characterization data necessary to make general statements of streak camera specification.

Further contribution and comments on the completeness, correctness and relevance of this parameter specification is encouraged and welcomed. Please send such contributions to Noel Fleurot (CEA-Limeil-Valenton) or Gary L. Stradling (Los Alamos National Laboratory). Those interested in being included in future communications from this committee should send their name, address and telephone number to one of the above co-chairmen.