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ARGONNE'S NEW WAKEFIELD TEST FACILITY*

J.D. Simpson+#
Argonne National Laboratory
Argonne, Illinois 60439, USA

ABSTRACT

The first phase of a high current, short bunch length electron beam research facility, the AWA, is near completion at Argonne. At the heart of the facility is a photocathode based electron gun and accelerating sections designed to deliver 20 MeV pulses with up to 100 nC per pulse and with pulse lengths of approximately 15 ps (fw). Using a technique similar to that originated at Argonne's AATF facility, a separate weak probe pulse can be generated and used to diagnose wake effects produced by the intense pulses. Initial planned experiments include studies of plasma wakefields and dielectric wakefield devices, and expect to demonstrate large, useful accelerating gradients (> 100 MeV/m). Later phases of the facility will increase the drive bunch energy to more than 100 MeV to enable acceleration experiments up to the GeV range. Specifications, design details, and commissioning progress are presented.

1 INTRODUCTION

Among the various schemes proposed in recent years for high gradient acceleration (100 MeV/m and higher), wakefield technology is perhaps one of the most straightforward. Numerous experiments performed using ANL's AATF facility have confirmed the validity of many wakefield concepts in structures, plasma, and dielectric loaded wave guides.

A new facility, the Argonne Wakefield Accelerator (AWA), is now under construction. Using it, wakefield and similar research will be possible at significantly higher levels of field excitations than were possible using the AATF. Non-ANL experimenters will be able to arrange use of the facility. This report outlines the principal features of the AWA, initial planned experiments, and the current status of the project.

Designed beam parameters for the initial phase of the AWA are:

Drive beam:	energy		20	MeV
	charge	≤	100	nC
	pulse length(fw)	≈	20	ps
	rep. rate	≤	30	pps
	emittance (rms)	≈	300	mm-mrad
Witness:	energy	≈	4	MeV
	pulse length(fw)	≈	10	ps
	charge	≤	1	nC
	emittance		(small)	

Instrumentation for experiments includes a spectrometer (0.1 % $\delta p/p$ resolution and angular deflection ≈ 1 mrad), and a streak camera.

2 EQUIPMENT DESCRIPTION

The principal design challenge and heart of the facility is the generation and acceleration of the 100 nC short bunches which form the drive beam. The adopted solution uses a photocathode based rf gun employing several special techniques followed by beam load tolerant linac sections. Components of the facility are indicated in Figure 1. The actual facility is installed in a shielded enclosure inside an existing hi-bay building managed by ANL's High Energy Physics Division.

2.1 Photo-cathode gun

Photo-cathode based gun designs commonly strive for low emittance. This usually limits beam pulse charges to tens of nC. Small emittance drive beam is not critical for wakefield applications, relaxing considerably some design constraints for the AWA gun. Several special techniques are also introduced in the AWA gun design [1] to meet the high charge goal. These include:

2.1.1 Large cathode area A circular area of 2 cm diameter is illuminated by the UV laser. This large diameter reduces: (1) the resulting beam divergence (resulting mainly from transverse space charge forces) to an acceptable value of about 250 mrad; (2) the longitudinal space charge fields; and (3) the laser power

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+ E-mail address: JDS@ANHEP2.HEP.ANL.GOV

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density which can potentially damage the cathode surface.

2.1.2 Curved laser pulse shape The 2 ps laser pulse is modified to have a roughly a spherically concave shape as in arrives at the cathode. This shape is produced in the laser optics system by reflecting it from the ends of

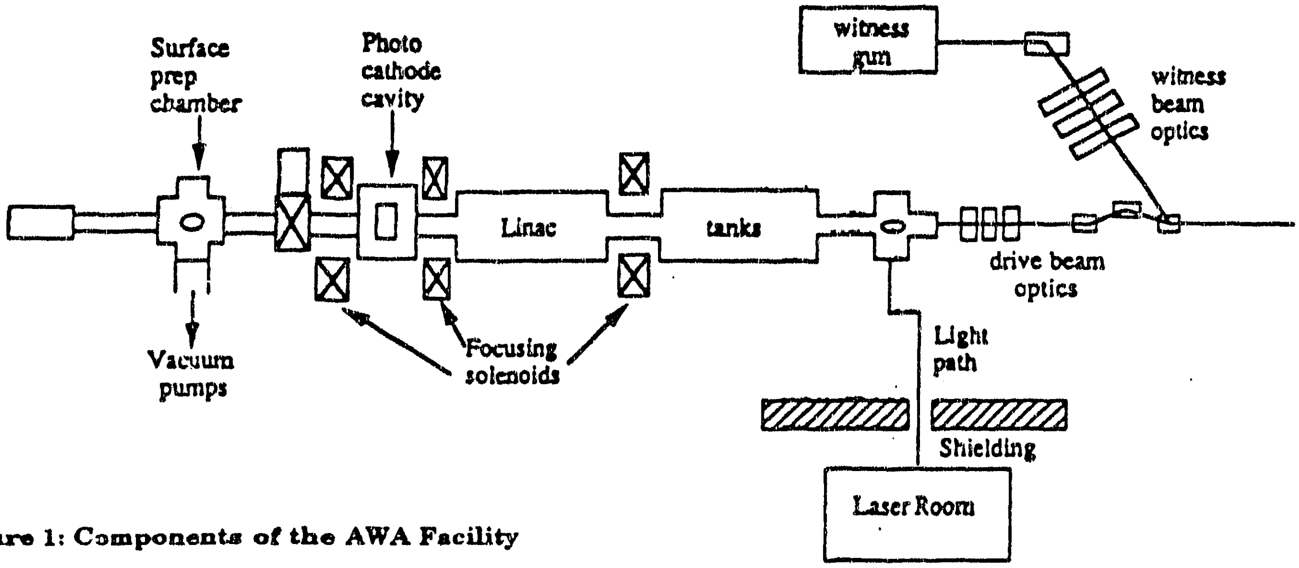

Figure 1: Components of the AWA Facility

a set of concentric cylinders (Figure 2). The relative positions of these cylinders adjustable remotely. A sagitta of about 18 ps has been identified as a reasonable starting point.

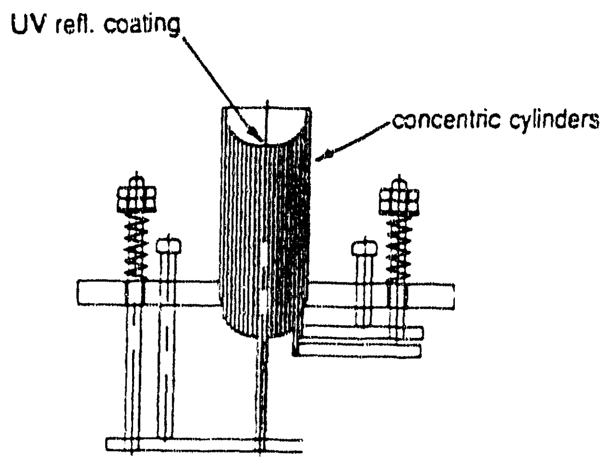

Figure 2: Laser pulse shaping reflector

Electrons are emitted from the cathode in a similar form, initially at the outer cathode diameter. This has two important benefits. First, it reduces significantly the radial space charge forces as the electrons are accelerated because of relativistic effects. Second, it allows "longitudinal compression" of the pulse due to the longer path taken by the outer electrons through the gun and pre-accelerator.

2.1.3 Nonlinear focussing As result of space charge forces and the gun cavity's rf field shape there exists strong correlation between the energy of the electrons and their radial position (and angle) as they exit the gun (Figure 3). Spherical aberration is intentionally introduced into the solenoidal focussing field by the geometry of the iron poles. The effect is chromatic correction in the overall focus through the system.

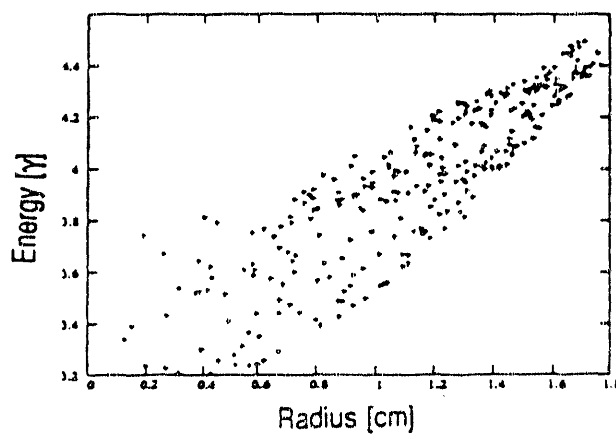

Figure 3: Energy vs radius of electrons at gun exit

Figure 4 shows a typical ray trace of a 100 nC bunch to a waist at the end of the pre-accelerator.

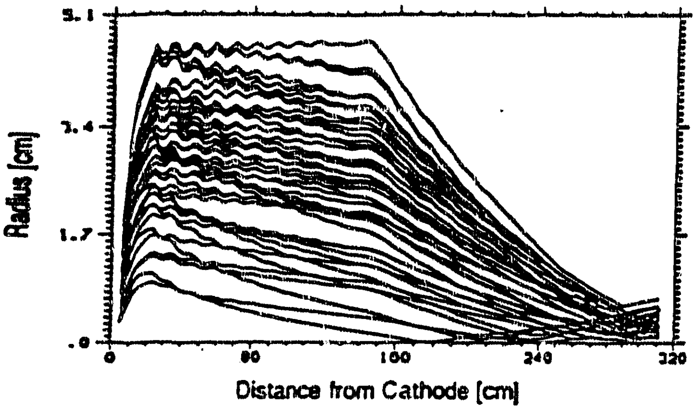

Figure 4: Ray-trace of typical beam pulse (gun through pre-accelerator)

2.2 Pre-accelerator

A distinct feature of the 20 MeV, 1.3 GHz, two-section pre-accelerator is its large iris size, 10 cm diameter. This is required to reduce the wake induced energy spread and possible bunch-to-bunch deflection problems when operating with more than one bunch per macropulse. The large apertures produce a large group velocity, β~0.17. A standing wave mode is therefore used to achieve about 8 MeV/m with 10 MW/m of rf power.

2.3 Witness beam source

Whereas in the AATF a witness pulse is generated from part of a single drive bunch and delayed by varying its beam line path length, the AWA employs a separate gun for its witness bunch. Witness delays up to 10 ns are possible. Only a fraction of a nC charge is required for the witness bunch, and several gun options have been examined.

At this time, we are looking seriously at the use of a dielectric (99.8% density alumina) loaded standing wave cavity. Bench measurements indicate that a TM_{014} cavity will produce about 4 MeV electrons with 3-4 MW of rf power. Although a conventional copper cavity is a straight forward option, the dielectric cavity may offer advantages in producing low emittance. A decision will be made soon as to what type witness gun is built.

2.4 Laser

The AWA laser system is described fully in a companion paper at the conference [2].

3 INITIAL EXPERIMENTS

A first and crucial experiment is to generate the high current beam pulses for which the facility is designed. Presently planned wakefield related experiments include the following.

3.1 Field gradient limits

Little is known of surface breakdown phenomena at the high frequency (~20 GHz) and short pulses (a few nsec) characteristic of the wakefield work most interesting to the ANL Group. Systematic studies will seek to determine breakdown limits and possible control by, for example, external magnetic fields.

3.2 Wake field transformers

The additional parameter of a dielectric constant in loaded wave guide tubes makes it possible to step up the longitudinal field with little or no change in group velocity [3]. Various transformers, some using deflecting mode traps [4], will be tested. Extremely high accelerating gradients of several hundred MeV/m will be demonstrated in these tests unless, as noted above, breakdown defines unfortunate limits.

3.3 Plasma wakes

There exist proposals to study plasma wakes in the recently identified "blowout" regime. Gradients up to 1 GeV/m may be possible in the proposed tests.

4 SCHEDULE

Beam tests are scheduled to commence in the fall of 1992. This schedule is presently paced by the delivery schedule of the main 1.3 GHz rf power supply.

Later phases for the AWA project are contingent to a large degree upon the success of Phase-I described here. Phase-II would provide higher energy drive beam (100-150 MeV) and Phase-III would demonstrate staging and other techniques to demonstrate 1 GeV acceleration at an average rate exceeding 100 MeV/m.

References

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