THE ARGONNE WAKEFIELD ACCELERATOR-OVERVIEW AND STATUS*

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Abstract

The Argonne Wakefield Accelerator (AWA) is a new facility for advanced accelerator research, with a particular emphasis on studies of high gradient (~100 MeV/m) wakefield acceleration. A novel high current short pulse L-Band photocathode gun and preaccelerator will provide 100 nC electron bunches at 20 MeV to be used as a drive beam, while a second high brightness gun will be used to generate a 5 MeV witness beam for wakefield measurements. We will present an overview of the various AWA systems, the status of construction, and initial commissioning results.

Introduction

The goal of the AWA program is to develop wakefield based high gradient acceleration techniques for future linear colliders. In the process of developing the drive beam previously unexplored regimes of rf photocathode source operation will be investigated.

The AWA project is planned as a series of phases, leading up to a 1 GeV demonstration linac based on wakefield technology. Phase I of the AWA is presently nearing completion, and consists of an L-band 20 MeV drive linac and photocathode source capable of delivering 100 nC, 20 ps (FWHM) pulses, a 5 MeV high brightness photocathode gun to provide a witness beam as a probe of wakefields generated by the drive beam, and associated instrumentation for beam monitoring and wakefield measurements. A plan view of AWA Phase I is shown in figure 1. Additional details of the various AWA subsystems may be found in other papers at this conference ([1-4]).

High Current Photocathode Source and Drive Linac

At the core of the AWA is a laser photocathode source, capable of delivering 2 MeV, 100 nC electron bunches to the drive linac. The source represents a significant extension of present photocathode gun capabilities, and several novel techniques have been developed to deal with the challenge of generating a beam of this intensity. Details of the gun design and beam dynamics simulations may be found in reference [5].

*Work supported by U.S. Department of Energy, Division of High Energy Physics, Contract W-31-109-ENG-38

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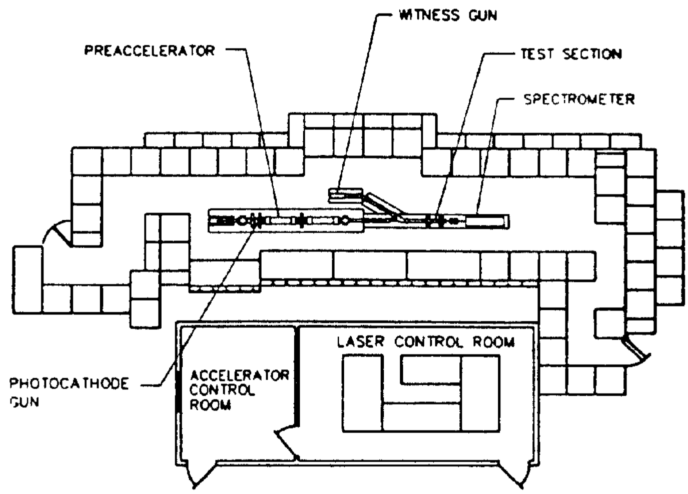

Figure 1. Plan view of AWA Phase I

In order to minimize radial space charge forces during the photoemission process, a large photocathode (2 cm diameter) is used. In addition, a curvature of the laser wavefront is induced using special optics [1]. Simulations indicate an optimal shape for the laser wavefront to be concave (electrons farther out in radius are emitted first), with a sagitta of 17 ps.

There is a strong correlation between the radial position and energy of the electron pulse emitted from the gun. In order to minimize the spot size at the exit of the drive linac, solenoids employing nonlinear focussing (spherical aberration) were designed. The shape of the magnetic field can be modified if necessary by changing the iron pole pieces.

Two standing wave iris-loaded cavities are used to accelerate the drive beam to 20 MeV [3]. In order to minimize wakefield effects in the linac, large diameter (10 cm) irises are used. The drive linac is shown in figure 2.

Witness gun and wakefield measurement system

The witness gun [4] is used to generate a low current, small emittance pulse which acts as a probe of wakefields generated by the drive bunch. A 6-cell iris-loaded L-band cavity operating in the $2\pi/3$ mode produces 0.1 nC, 5 MeV bunches with a transverse emittance

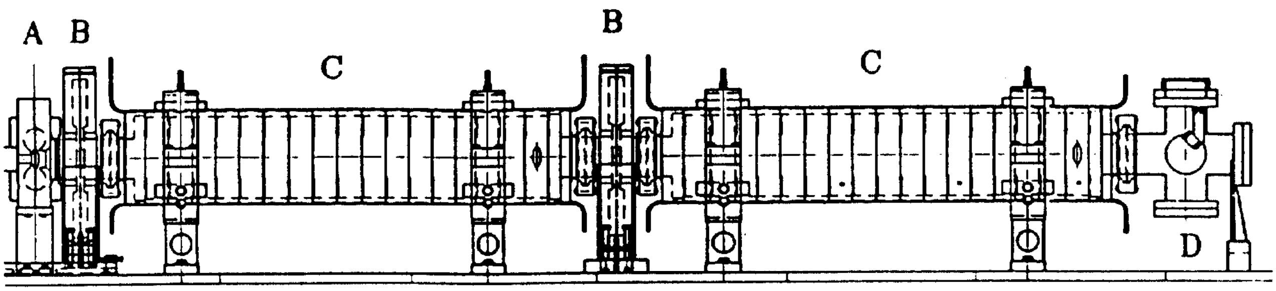

Figure 2. Drive linac. A: Photocathode gun, B: Nonlinear focussing solenoids, C: Linac cavities, D: Laser injection port. The bucking solenoid which nulls the magnetic field at the photocathode is not shown.

$\leq 1\ \pi$ mm-mrad. The delay between the witness and drive bunches is adjusted by varying the witness gun rf and laser injection phases simultaneously.

A simple chicane is used to transport the drive and witness bunches through the test section containing the wakefield device under measurement. For the initial experiments the drive and witness beams will pass collinearly through the test section. Measurements requiring noncollinear (parallel) drive and witness bunches, such as those involving wakefield transformer structures (see below) are possible with a slight reconfiguration of the beamline.

After passing through the test section, the beams are diagnosed using a magnetic spectrometer. A typical wakefield experiment involves measuring the energy modulation and transverse deflection of the witness bunch as a function of the relative drive-witness delay.

Laser

The AWA laser system is used for both drive and witness beam generation. The laser can produce 8 mJ, 2 ps pulses at 248 nm. This is sufficient to permit the use of robust but low quantum efficiency photocathode materials such as Yttrium or Copper.

An annular mirror array [1] is used to introduce a curvature of the laser wavefront for drive beam generation. The laser pulse delivered to the witness gun is not shaped.

Diagnostics

The AWA will make extensive use of luminescent screen beam position monitors viewed by CCTV cameras. The video signal can be digitized for analysis and storage [2]. Button pickups for nondestructive monitoring will be located at various places around the AWA beamlines.

Gas Cherenkov cells are used to diagnose the pulse length of the 20 MeV drive beam. The duration of the Cherenkov light flash can be measured by the streak camera with a 2 ps resolution.

Diagnosing the 2 MeV high current source presents special problems. The transverse bunch shape can be measured using a luminescent screen, but the bunch energy is too low for gas Cherenkov cells to be used as longitudinal diagnostics. Multiple scattering effects in general limit the utility of higher refractive index radiators.

A diagnostic to measure the shape of the leading edge of the drive bunch at the gun exit is under development and is shown schematically in fig 3. A series of quartz beads are strung on a thin tungsten wire. Cherenkov light generated by the beam impinging on the bead array is transported to the streak camera. Because of multiple scattering and multiple reflection effects the streak length gives only an upper limit on bunch length at that point. However, the start of each streak gives the time of arrival of the leading edge of the bunch at the corresponding bead.

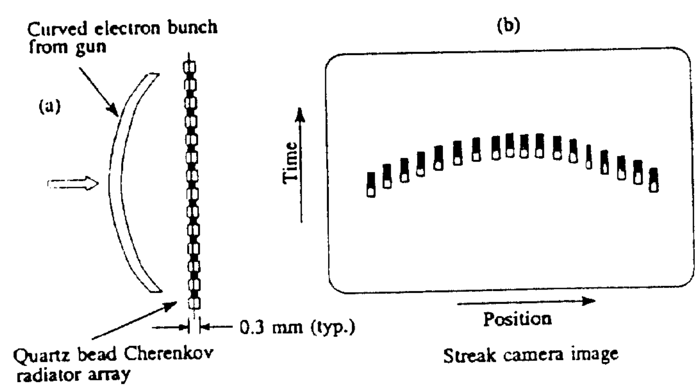

Figure 3. Bead array diagnostic for measuring the shape of the electron pulse emitted from the rf gun.

Experimental program

The generation of 20 ps, 100 nC electron bunches from the drive linac is in itself an important experiment. Of particular interest is the characterization of the drive gun and comparison of measured beam parameters with the predictions of the codes used for the design simulations.

The first wakefield experiments will concentrate on the study of breakdown, charging and radiation damage effects in high gradient collinear dielectric structures. These issues will need to be resolved for any practical dielectric-based wakefield accelerator.

The noncollinear drive-witness configuration will be used to investigate wakefield transformer schemes which offer the potential of generating high accelerating gradients without the stringent injection tolerances required by collinear geometries to suppress single bunch beam breakup effects. One particular class of devices being developed by the AWA group are coupled wake tube structures [6]. The wake generated by the drive bunch in a dielectic loaded guide is transferred via quarter wave matching section to a smaller bore accelerating structure. Figure 4 shows a numerical calculation of the gradient step up for a particular geometry as a function of matching section length, demonstrating that the expected transfer efficiency can be attained. Note that the optimum matching section length is, as expected, slightly less than $\lambda/4$ due to end effects.

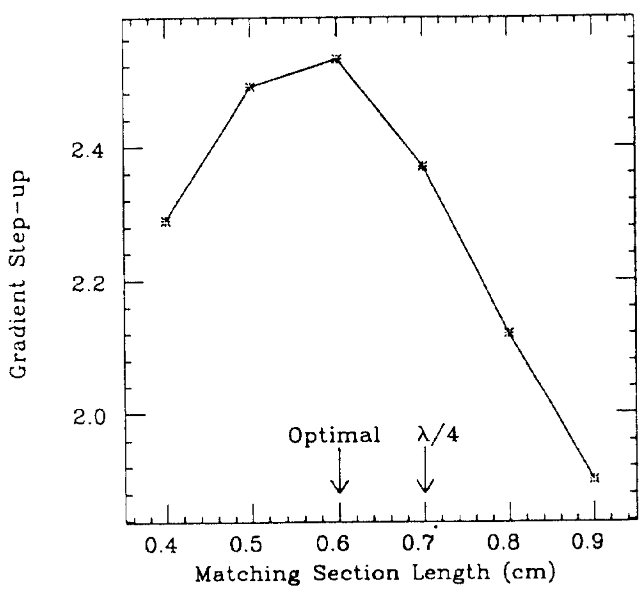

Figure 4. Numerical simulation of gradient step up as a function of matching section length for a 20 GHz coupled wake tube transformer. The expected step up of 2.5 is attained.

The drive bunch generated at the AWA is sufficient to perform the first experimental investigations of the Briezman effect in plasma wakefield acceleration [7]. In this regime all electrons are ejected from the plasma behind the drive bunch, resulting in extraordinary gradients. The plasma wakefield experiment planned at the AWA is predicted to generate gradients of 1 GeV/m.

Status and Commissioning

The drive linac components have been fabricated and assembled, and witness gun fabrication is underway. After a setback due to the default of the vendor, the rf system is nearing completion, and cavity conditioning in expected to begin this summer. Commissioning of Phase I of the AWA will be completed by the end of CY1993.

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