AN UPDATE ON ARGONNE'S AWA*

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Abstract The Argonne Wakefield Accelerator (AWA) is a new research facility which will possess unprecedented research capabilities for the study of wakefields and related areas requiring short, intense electron bunches. The AWA is designed to produce 100 nC, 14 ps (full width) electron bunches at rep rates up to 30 Hz. Phase-I of the AWA, now under construction, will provide these pulses at 20 MeV for various experiments. Current designs, related research and development, and construction status are presented in this general overview and project update.

Introduction

Phase-I of the Argonne Wakefield Accelerator (AWA) project [1] has as its major goal the development of tools to study high gradient (100 MV/m scale) wakefield acceleration. The new facility will consist of

- a high current, short pulse photocathode electron source
- a standing wave linac section specially configured for heavy beam loading (the preaccelerator)
- a wakefield measurement system

The overall layout of this phase of the AWA is shown in figure 1. Subsequent phases of the AWA will incorporate additional linac sections to increase the beam energy to > 100 MeV and an upgrade of the laser system and optics to produce multiple drive bunches, with the eventual goal of demonstrating the acceleration of a beam to over 1 GeV using wakefield technology.

Electron Source and Preaccelerator

The AWA electron source is shown in figure 2. It consists of an L-band rf gun cavity, cathode surface preparation chamber and positioning system, a focusing solenoid to match the beam from the source into the preaccelerator, and a bucking coil to cancel the axial magnetic field at the photocathode. This design incorporates some innovative features which permit the generation of 100 nC bunches while minimizing longitudinal and transverse space charge blow-up. A large (2 cm diameter) photocathode is used, and the laser wavefront is shaped to compensate geometric pulse lengthening effects [1,2].

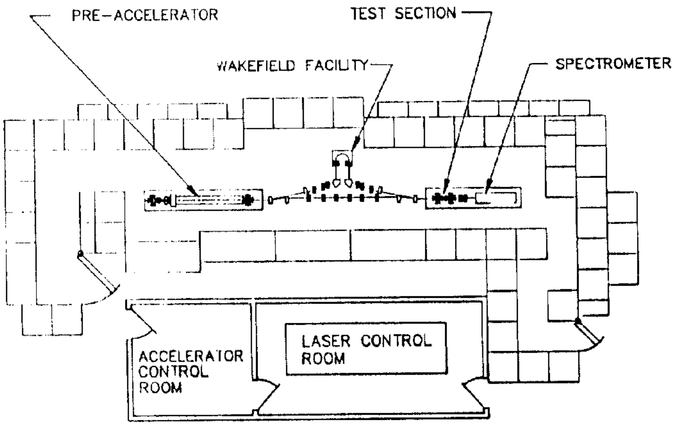

Figure 1: Plan view of Phase-I of the Argonne Wakefield Accelerator.

Beam dynamics in the gun have been simulated with a modified version of the PARMELA code [3]. Consistency checks have also been performed using TBCI-SF and analytic models. For a 100 nC bunch, the codes estimate the normalized transverse emittance to be 400π mm-mr, which is acceptable for our applications. The bunch energy at the exit of the gun cavity is 1.7 MeV, with a full width ($\pm 4\sigma$) of 14 ps.

Yttrium is the initial choice as the photocathode material for its robust vacuum and surface properties. It is not easily contaminated by accidental exposure to air and has a quantum efficiency of several times 10^{-4}. Samarium or Copper photocathodes may also be studied. The photocathode can be retracted into a vacuum chamber for surface preparation. We will initially use a simple scraping process to remove oxides from the photocathode surface.

The photocathode requires at least 1 mJ per pulse to generate a 100 nC beam pulse. Laser requirements for the AWA source (sufficient for all subsequent phases of the project) are:

Wavelength	248 nm
Pulse length	< 2 ps
Energy	> 5 mJ/pulse
Timing jitter	< 3 ps
Energy jitter	< 10%

The laser source energy is designed to account for losses in optics and air. A feed-forward based system is currently under development which will further reduce the pulse to pulse intensity jitter to 2%. This scheme will be discussed in another paper at these proceedings [4].

Fine adjustments of the gun cavity frequency will be accomplished by the photocathode positioning system.

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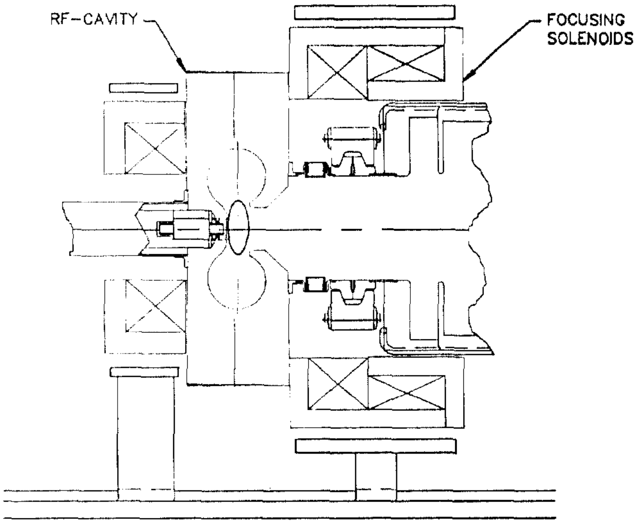

Figure 2: AWA photocathode electron source.

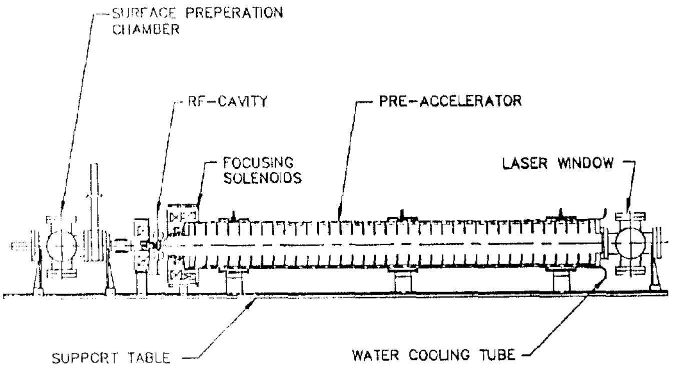

Figure 3: AWA photocathode gun and preaccelerator.

Bench measurements on the prototype cavity have demonstrated that the cathode position can be used to adjust frequency at a sensitivity of 3.2 MHz/mm. The positioner will probably be a fine micrometer driven by a stepper motor. Special care will be taken to ensure solid rf contact of moving parts.

The required shape of the focussing field was determined by optimizing transmission and bunch shape in the PARMELA simulations. Final design of the focussing and bucking solenoids was accomplished using the PE2D code [5] and was based on reproducing as closely as possible the optimal PARMELA field pattern from physically realizable magnets.

The preaccelerator is an iris-loaded structure designed to accelerate the bunches delivered by the photocathode gun to 20 MeV for wakefield experiments. The complete AWA front end (prep chamber, photocathode gun, and preaccelerator) is shown in figure 3.

Beam loading in the preaccelerator is quite large given the 100 nC electron bunch charge. The L-band (1.3 GHz) standing-wave linac designed for phase-I of the AWA consequently has a high group velocity, ($\beta_g = 0.139$) with aperture radius $a = 5.08$ cm and outer wall radius $b = 10.04$ cm. A standing-wave linac was chosen as the first linac stage, as opposed to traveling-wave, in order to obtain a reasonable accelerating gradient, $\sim 10\,\mathrm{MV/m}$, given available rf power, 20 MW, under such severe beam-loading conditions. The shunt impedance of the linac is $r_s = 21\,\mathrm{M\Omega/m}$ yielding a longitudinal wake-function for the fundamental mode $W = 5.14\,\mathrm{kV/m/nC}$. This gives a bunch-to-bunch energy spread (in multiple drive bunch operation) of $\sim$ 7% after two meters and a head-tail energy spread of $\sim$ 14%, where the approximate factor of two difference is due to several higher order modes being in a coherent decelerating phase within the bunch.

Wakefield Measurement System

The wakefield measurement system for the AWA is based on the same principles as the one developed and successfully demonstrated at the Argonne Advanced Accelerator Test Facility (AATF) [6]. The available drive bunch intensity at the AWA will be a factor of 40 larger than that of the AATF, and the bunch length a factor of two smaller. This permits experiments to be carried out at higher frequencies and with much larger wakefield amplitudes.

Unlike the AATF, where the witness bunch is produced by degrading a fraction of the linac beam in a target, the AWA will produce its witness beam by splitting off a small portion of the laser pulse and causing it to impinge on the photocathode approximately 3 1/8 rf periods in advance of the main pulse. In this way the witness bunch is produced with roughly half the drive beam energy allowing later magnetic separation of the two bunches, and will also be unaffected by the drive beam wakefields in the gun and preaccelerator cavities. The witness intensity ($\sim$ 1 nC) will be larger than that available at the AATF, greatly facilitating wakefield measurements.

After exiting the preaccelerator, the drive and witness bunches are separated across a magnetic septum. A trombone timing system (figure 4) re-using many components and the associated magnetic spectrometer from the existing AATF analyzer will be used for diagnosing experiments. The high energy, high charge (driver) bunch follows the shorter path, while the witness bunch passes through the variable length trombone section. The two beams are then recombined magnetically to pass along parallel trajectories through the wakefield device under test. The system can preserve beam emittance and short pulse length for drive-witness bunch delays of -200 ps to +1000 ps, as in the AATF. The energy and transverse deflection of the witness bunch as a function of its delay with respect to the

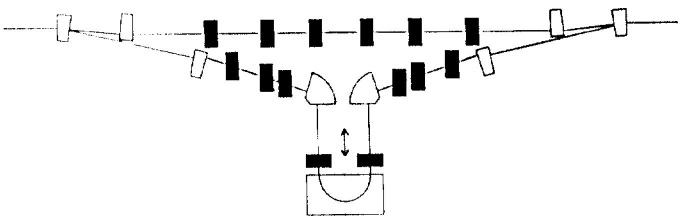

Figure 4: Dual beamlines for producing variable drive-witness beam delays. The arrow indicates the trombone section. Filled (open) boxes are quads (dipoles).

drive bunch provide a sensitive probe of the longitudinal and transverse wake potentials in the test device.

Program Status

The AWA is in the beginning stages of construction. The contracts for the rf and laser systems are about to be signed. The delivery time on the rf system is expected to be approximately 9 months. The laser will be delivered and installed by September of 1991. The radiation shielding is now in place with the minor exception of a second exit for fire safety. Construction of the control/laser room will begin shortly, and we expect this to be completed by the end of June 1991. Mechanical support structures have been designed but not finalized. Most of these details will be worked out in the next several months to accommodate power supply cables, cooling tubes, and vacuum system components.

Prototype gun and preaccelerator cavities have been subjected to extensive low power (network analyzer) testing. Coupling of rf power to the gun cavity has been optimized using an elliptical slot. The coupling of rf to the preaccelerator linac has not yet been bench tested, but there are several options now being analyzed. As with any accelerating cavity the detailed fine tuning of the matching of waveguide to structure is in the end a matter of trial and error.

Most of the important cavity components have been cut and heat treated. Copper rough cuts to be used for the photocathode cavity and the preaccelerator have been fabricated and heat treated to ensure that no inclusions will remain to damage the surface of the copper during the final brazing process. Some blistering occured which can be removed in the final machining. Final surface finishing will be an electropolish to ensure a very smooth ($\sim 2\ \mu$m) finish. The final brazing operation will not change the surface finish since any inclusions were baked out in the first step.

High power tests of the gun cavity are planned for the near future. Because of the long lead time on the AWA rf system, power for these experiments will be provided by the Chemistry Division linac (used by the AATF). Breakdown and dark current measurments will be particularly emphasized.

Phase-I of the Argonne Wakefield Accelerator project is now underway. Fabrication of the photocathode cavity and preaccelerator linac has started. Barring major glitches we will be extracting the first 100 nC, 14 ps bunches by the summer of 1992. Initial wakefield experiments at the AWA will concentrate on dielectric loaded structures. A series of plasma wakefield and plasma focussing experiments are also being planned.

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