ISBN: 978-3-95450-132-8 doi:10.18429/JACoW-IPAC2014-TUPME058

THE ARGONNE WAKEFIELD ACCELERATOR (AWA): COMMISSIONING AND OPERATION*

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Abstract

The commissioning of the upgraded AWA facility is well underway. The new L-band electron gun has been fully commissioned and has been successfully operated with its Cesium Telluride photocathode at a gradient of 80 MV/m. Single bunches of up to 100 nC, and bunch trains of up to 32 bunches with a total charge of 600 nC have been generated. The six new accelerating cavities (L-band, seven cells, pi mode) have been RF conditioned to 12 MW or more; their operation at 10 MW brings the beam energy up to 75 MeV. Measurements of the beam parameters are presently underway, and the use of this intense beam to drive high gradient wakefields will soon follow. One of the main goals of the facility is to generate RF pulses with GW power levels, corresponding to accelerating gradients of hundreds of MV/m and energy gains on the order of 100 MeV per structure.

UPGRADED AWA FACILITY

The main mission of the Argonne Wakefield Accelerator Facility (AWA) is to develop technology for future accelerator facilities. The AWA facility has been used to study and develop new types of accelerating structures based on electron beam driven wakefields. In order to carry out these studies, the facility employs a photocathode RF gun capable of generating electron beams with high bunch charges and short bunch lengths. This high intensity beam is used to excite wakefields in the structures under investigation, thus being referred to as the Drive Beam. There is a second electron beam that is used to probe the wakefields generated by the Drive Beam, and it is referred to as the Witness Beam. Figure 1 shows a schematic of the AWA bunker and beamlines.

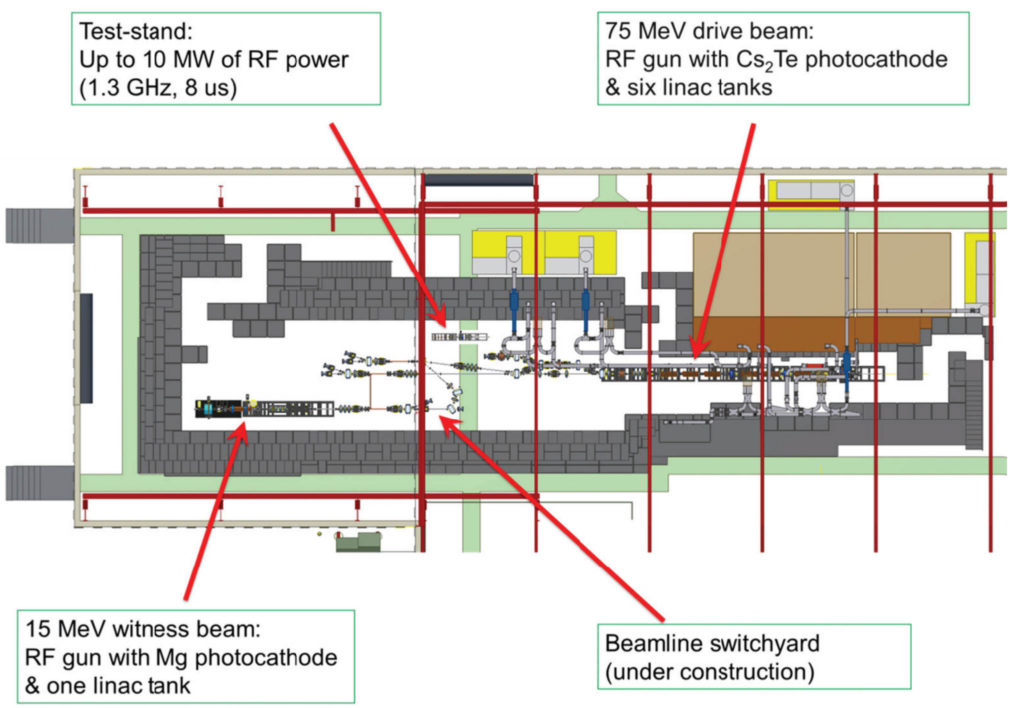

Figure 1: Schematic of the of the AWA bunker and beamlines. Topview of the bunker showing the Drive Beamline and the Witness Beamline. Also shown is a small test-stand used to carry out experiments (independently) that require high RF power from the klystrons.

*Work supported by the U.S. Department of Energy under contract No. DE-AC02-06CH11357
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The facility is also used to investigate the generation and propagation of high brightness electron beams, and to develop novel electron beam diagnostics. More recently, the facility has attracted interest from the broader scientific community, and collaborations on a wider range of topics have been fostered by the DOE-HEP stewardship initiative.

The AWA high intensity drive beam is generated by a photocathode RF gun, operating at 1.3 GHz. This one-and-a-half cell gun typically runs with 12 MW of input power, which generates an 80 MV/m electric field on its Cesium Telluride photocathode surface. Six 1.3 GHz accelerating structures have been fabricated, installed and RF conditioned as part of the recent facility upgrade. These new accelerating structures [1] are seven-cell standing-wave π mode structures, designed to operate with 10 MW of input power and 11.2 MeV energy gain. Thus, their operation will increase the energy of the beam produced by the drive gun from 8 MeV to 75 MeV. This will, of course, allow significantly more energy to be extracted from the drive beam as it drives wakefields in the structures under test. The higher beam energy also implies a smaller physical transverse emittance of the bunches, facilitating their propagation through smaller aperture wakefield structures, and generating even higher wakefield amplitudes.

The charge of the electron bunches can be easily varied from 0.1 to 100 nC, by varying the energy of the laser pulse incident on the photocathode. The high quantum efficiency of the Cs_2Te photocathode – routinely made in house and reaching over 15% – makes it possible to generate high charge bunches with laser pulses of relatively low energy. Thus, the laser pulse can be split into a sequence of laser pulses separated in time by one RF period, and this laser pulse train can be used to generate an electron bunch train.

The AWA laser system consists of a Spectra Physics Tsunami oscillator followed by a Spitfire regenerative amplifier and two Ti:Sapphire amplifiers (TSA 50). It produces 1.5 mJ pulses at 248 nm, with a pulse length of 2 to 8 ps FWHM and a repetition rate of up to 10 pps. A final KrF Excimer amplifier is optionally used to increase the energy per pulse to 15 mJ.

The so-called beamline switchyard (Fig. 2) is presently being constructed. It will connect the two beamlines, allowing wakefield experiments to be performed using either the collinear configuration, in which the drive and witness bunches travel along the same structure, or the two-beam-accelerator configuration, in which RF power is transferred from the drive beam decelerating structure to the witness beam accelerating structure, by means of a waveguide.

COMMISSIONING

The Drive Gun and the first accelerating cavity have been fully commissioned, reaching full RF power levels and yielding electron beams of up to 19 MeV and bunch charges of 100 nC for single bunch, and 600 nC for bunch trains. Bunch trains of various numbers of bunches have been generated: 2, 4, 8, 16, and 32. The train of 32 bunches has a bunch separation equal to one RF period of the 1.3 GHz gun frequency. Figure 3 shows the signals from the Bergoz Integrating Current Transformer (ICT) and Fast Current Transformer (FCT) when bunch trains are generated. The calibrated ICT signal gives the value of the total charge in the train, and the FCT signal shows the relative amplitude of the various bunch charges and the total time duration of the bunch train.

The remaining five accelerating cavities have been RF conditioned individually but have not accelerated the Drive Beam yet. The documentation related to safety assessment and procedures has just been approved, and the integration of these accelerating cavities into the beamline operation is imminent.

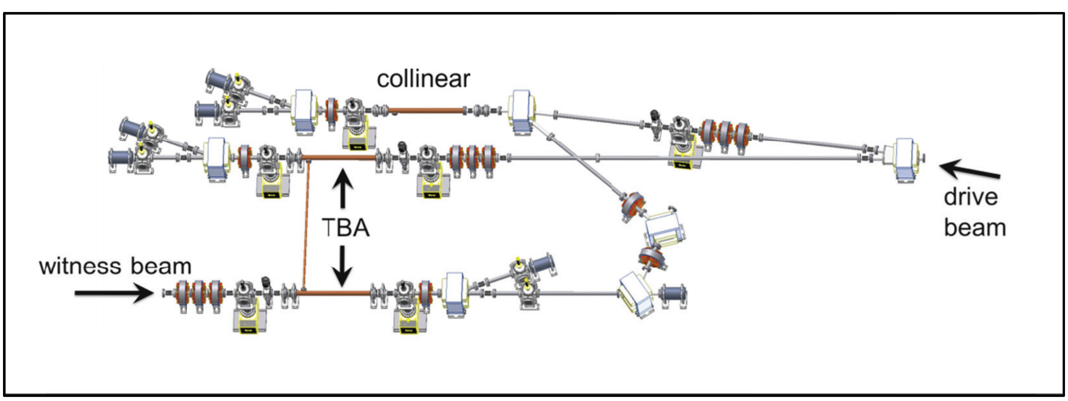

Figure 2: Schematic of the of the beamline switchyard, showing the branch for collinear wakefield acceleration experiments, and also the two parallel beamlines (connect by a waveguide section) meant to operate the two-beam-accelerator (TBA) experiments

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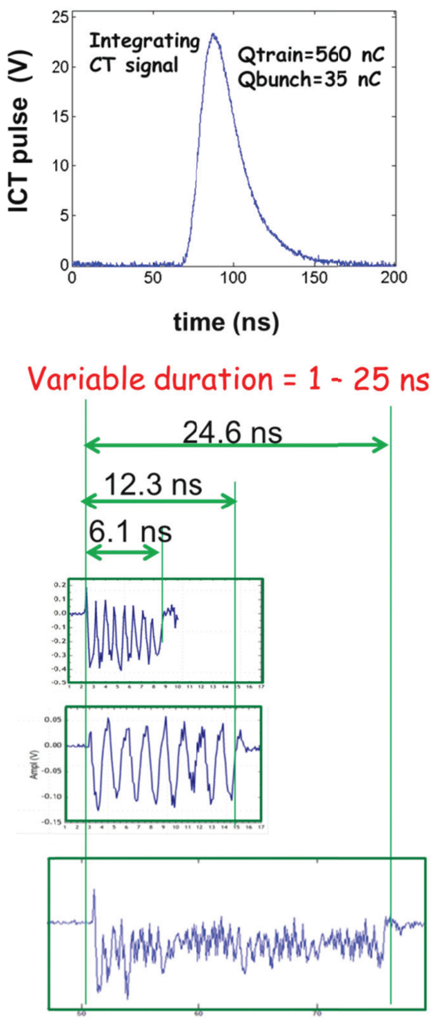

Figure 3: Oscilloscope traces from the ICT and FCT, showing total charge in a bunch train (ICT), and three examples of FCT traces for increasingly longer bunch trains.

WAKEFIELD ACCELERATION

The use of electron beam driven wakefields to achieve high gradient acceleration has received considerable attention. It offers the advantage of using a relativistic beam to transport the energy to the accelerating structures, decreasing the difficulties of generating and distributing RF power by conventional means; wakefields naturally constitute RF pulses that are of short duration and high peak intensity [2].

Research at the AWA facility has been exploring various types of wakefield structures, including photonic band gap structures, metallic iris loaded structures, and also more exotic schemes using metamaterials. The main focus of the facility, however, has clearly been the development of dielectric loaded structures. They offer the advantage of simple geometry and easy fabrication with accelerating properties that compare favourably with conventional iris loaded metallic structures: the axial electric field is uniform across the transverse cross section of cylindrical structures, and the uniform cross section of the structures presents no geometric features to cause field enhancement. The damping of the undesirable deflecting dipole modes seems to be more easily accomplished in dielectric loaded structures as well; planned experiments will explore the use of longitudinal slots on the metallic outer shell of dielectric structures, as a possible scheme to damp dipole modes. Dielectric structures also hold the promise of withstanding higher electric fields without material breakdown. A significant advantage offered by wakefield structures, in comparison with other wakefield schemes, is the ability to accelerate positron bunches or electron bunches in basically identical fashion.

In the past few years AWA has demonstrated high gradient fields (100 MV/m) in dielectric based wakefield structures [3]. Generation and extraction of RF power using beam driven dielectric structures has also been demonstrated [4 - 6]. Several experiments exploring new designs and new features of dielectric based wakefield structures will be conducted in the near future.

Once the upgrades are completed, the goal is to achieve accelerating gradients on the order of 0.5 GV/m in structures with approximately 3 mm apertures. The generation and extraction of RF pulses with power levels on the order of GW shall also be demonstrated.

REFERENCES

[1] J.G. Power et al, “Upgrade of the Drive Linac for the AWA Facility Dielectric Two-Beam Accelerator,” in proceedings of IPAC 2010, Kyoto, May 2010.
[2] W.Gai et al, “Short-pulse dielectric two-beam acceleration,” J. Plasma Physics, p. 1, Feb. 2012.
[3] M. Conde et al., “High Gradient Excitation and RF Power Generation using Dielectric Loaded Wakefield Structures,” in proceedings of LINAC’08, Victoria, September 2008.
[4] F. Gao et al., "Design and Testing of a 7.8 GHz Power Extractor Using a Cylindrical Dielectric-loaded Waveguide," Physical Review ST Accel. Beams 11, 041301(2008).
[5] F. Gao et al., "Multi-Nanosecond High Power Pulse Generation at 7.8GHz with a Dielectric-loaded Power Extractor," IEEE Transactions on Nuclear Science **56** (3), p. 1492 – 1497, (2009).
[6] C. Jing et al., "The First Experiment of a 26 GHz Dielectric Based Wakefield Power Extractor," in proceedings of IPAC 2010, Kyoto, May 2010.