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The status of normal conducting RF (NCRF) guns, a summary of the ERL2005 workshop

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Abstract

The 32nd Advanced ICFA Beam Dynamics Workshop on Energy Recovering Linacs (ERL2005) was held at Jefferson Laboratory, March 20–23, 2005. A wide range of ERL-related topics were presented and discussed in several working groups with Working Group 1 concentrating upon the physics and technology issues for DC, superconducting RF (SRF) and normal conducting RF (NCRF) guns. This paper summarizes the NCRF gun talks and reviews the status of NCRF gun technology. It begins with the presentations made on the subject of low-frequency, high-duty factor guns most appropriate for ERLs. One such gun at 433 MHz was demonstrated at 25%DF in 1992, while the CW and much improved version is currently being constructed at 700 MHz for LANL. In addition, the idea of combining the NCRF gun with a SRF linac booster was presented and is described in this paper. There was also a talk on high-field guns typically used for SASE-free electron lasers. In particular, the DESY coaxial RF feed design provides rotationally symmetric RF fields and greater flexibility in the placement of the focusing magnetic field. While in the LCLS approach, the symmetric fields are obtained with a dual RF feed and racetrack cell shape. Although these guns cannot be operated at high-duty factor, they do produce the best quality beams. With these limitations in mind, a section with material not presented at the workshop has been included in the paper. This work describes a re-entrant approach which may allow NCRF guns to operate with simultaneously increased RF fields and duty factors. And finally, a novel proposal describing a high-duty factor, two-frequency RF gun using a field emission source instead of a laser driven photocathode was also presented.

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1. Introduction (D. H. Dowell, SLAC)

This report summarizes the normal conducting RF (NCRF) gun presentations given in the Working Group I session at the Jefferson Lab ERL2005 Workshop. Although the re-entrant gun material of Section 3 was not presented in the workshop, we consider it to be very relevant to this topic and include it in this summary.

The report is organized into the following sections: Section 2 reviews the best-demonstrated performance for a NCRF gun at high-duty factor. Next Dinh Nguyen describes a next-generation NCRF gun LANL and AES have designed for CW operation. This 700 MHz gun is scheduled for completion in 2006 and should surpass many of the performance parameters of any previous NCRF system. Dinh also proposes combining the NCRF gun with a SRF booster linac for a hybrid injector design. In Section 4 Robert Rimmer applies experience gained in building the PEP-II cavities for the B-Factory at SLAC to propose a more efficient NCRF design. In his approach the cells are made with very re-entrant nose cones to increase the on-axis RF field, improve the shunt impedance and reduce the thermal stresses. Although this work was not presented in the working group, it has been included because of its relevance to the discussion of NCRF guns. Coaxial fed

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guns are described in Section 5. The principle advantages of this type of gun are the elimination of all RF field asymmetries and complete freedom in the placement of the emittance compensation solenoid. This gun has produced excellent quality beams for the VUV-FEL at DESY in Hamburg, Germany. Another approach to generating symmetric fields is given in Section 6. In this gun design for the SLAC/LCLS X-ray FEL, a rotationally symmetric field is achieved with dual RF feeds and an elliptical cavity shape. In Section 7, John Lewellen proposes a two-frequency gun to limit the time for field emission from a cathode stalk to a small portion of an RF cycle. In this way he eliminates the need for a drive laser. Section 8 is the summary.

2. State-of-the-art (D. H. Dowell, SLAC)

In terms of duty factor and average power operation, the Boeing/LANL 433 MHz gun remains the state-of-the-art. This gun was fabricated in 1988–1989 [1] and tested at high-average power from 1990–1992 up to 5 MeV beam energy [2]. In 1994–1996 it was incorporated into a higher energy accelerator (20 MeV) and was used as the electron source in bunch compression experiments demonstrating third-harmonic linearization of the longitudinal phase space [3]. Fig. 1 shows a photograph taken from the photocathode end of the gun. The cathode deposition chamber is in the foreground with the large RF waveguide feeds (black) connected at 45° (relative to vertical) to independently power the two gun cells.

Table I lists the parameters for the 433 MHz gun, which were demonstrated during the 1992 high-duty test. Unfortunately, the gun's performance was severely limited by poor vacuum which reduced the cathode lifetime to only 2–3 h [2]. This short lifetime was due to a vacuum leak from the water-cooling channels into the gun as evidenced by the large partial pressure of water.

The general configuration of this gun is given in Fig. 2. In this design, the emittance compensation coil is embedded (brazed) into the copper structure. This brazing distorted the embedded coil producing a large dipole kick. This dipole magnetic field was corrected using four permanent magnets clocked at 90° around the coil [4]. After correcting for the distortion, the rms emittance was measured to be fairly good at [4.4 + 1.1*Q(nC)] microns. The general shape of the gun cells can also be seen in Fig. 2. The re-entrant design allowed the relatively high rf field of 25 MV/m (peak) to be reached at high-duty factor. This same re-entrant shape for the nose cones is further optimized to reduce thermal stress as described in Section 4.

3. The Los Alamos/AES CW NCRF gun (D. Nguyen, LANL)

A key component of an energy recovery linac is a low-emittance, high-average-current electron gun. The electron beam's average current (~1 A) determines the electron bunch charge (~1 nC) and bunch repetition rate (~1 GHz). The most straightforward approach to achieve low emittance (~2 mm-mrad) at 1 nC bunch charge is through the use of the room-temperature RF photocathode gun. These qualities have been achieved with RF guns operating at low-duty factors. To date, a high-average-current RF photocathode gun, operating continuously at 100% duty factor, is yet to be demonstrated. The principal challenges of a high-duty-factor normal-conducting RF gun are

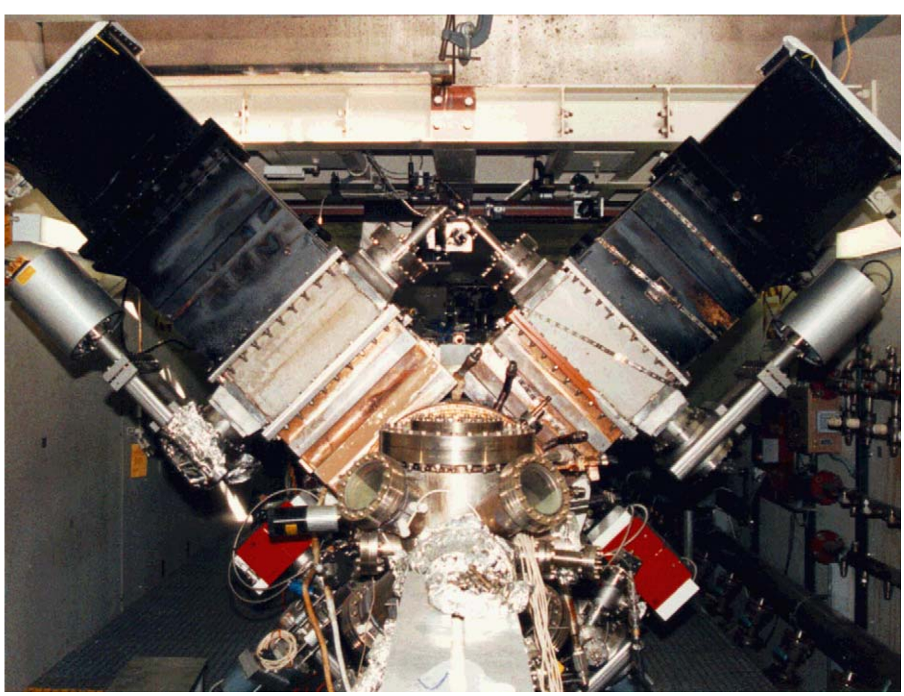

Fig. 1. Photograph of the Boeing/LANL 433 MHz NCRF gun in the test vault.