BROOKHAVEN NATIONAL LABORATORY
ER TECHNOLOGY TRANSFER
CRADA FINAL REPORT

DEVELOPMENT OF HIGH BRIGHTNESS ELECTRON GUN
FOR ADVANCED ACCELERATORS AND RADIATION SOURCES

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Abstract

Under this CRADA we have carried out a joint research and development program between the Accelerator Test Facility at the National Synchrotron Light Source Department at Brookhaven National Laboratory and Northrop-Grumman Corporate Research Center of Princeton New Jersey. The subject of this research was the development of an advanced laser photocathode RF electron gun for the generation of high brightness electron beams. The intent of this work was to enhance the performance of the electron gun recently developed at Brookhaven National Laboratory and to transfer this technology to the industrial participant that has expressed great interest in acquiring the manufacturing and physics design capabilities of this device. The design of this new RF gun has been investigated in great detail and a prototype has been built and partially tested. As a result of this CRADA Northrop-Grumman has acquired the technology and expertise in building laser-photocathode RF guns. This is evidenced by the success of the company in commercializing this product.

Background

Accelerator based radiation sources, such as synchrotron light sources, have proved their value to the scientific community at large. Even as third generation light sources, such as the APS at ANL are being built, fourth generation sources are becoming a subject of research (for example, see the proceedings of the Fourth Generation Light Source Workshop, H. Winick and M. Chornaccia editors, SSRL February 1992).

The generation and acceleration of high brightness electron beams are in the forefront of particle accelerator research, with wide ranging applications for generation of coherent radiation in the ultra violet and X-ray regimes as well as linear colliders. Brookhaven National Laboratory is one of the leading laboratories in the research and development of these sources as well as advanced wigglers and other synchrotron radiation technologies.

The National Synchrotron Light Source Department at BNL is designing a Fourth Generation accelerator-based UV/VUV radiation source that will provide picosecond and sub-picosecond pulses of coherent ultraviolet radiation for wavelengths from 300 to 75 nm. The

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peak pulse power is from 200 MW to over 1 GW. The UV-FEL will make possible new avenues of inquiry in time resolved studies of diverse fields including chemical, surface and solid state physics, combustion dynamics, atmospheric science, biology and material science.

The high brightness gun, linac, high power lasers, beam lines, diagnostics and other experimental facilities of the Brookhaven Accelerator Test Facility (ATF) give it unique capabilities for exploring these important R&D areas. The FEL experiments at the ATF are specifically designed to explore the short wavelength emittance limit of compact linacs utilizing high brightness electron sources.

In short wavelength FELs, the best method of generating the necessary high brightness (high current at a low emittance) electron beam is by a laser photocathode RF gun. The only other alternative is extremely high energy storage rings with a price tag that makes them impracticable for light source design. Thus RF photocathode guns provide the only practicable means of generating the electron beams that are needed for compact, short wavelength coherent radiation sources.

Anticipating new requirements associated with the integration of the gun with accelerator systems, we have begun to work together with Northrop-Grumman on physics issues of advanced guns. Our preliminary calculations suggest that a three and a half cells gun (compared to the present one and a half cells gun at the ATF) would provide higher brightness and greater immunity to emittance degradation in the accelerator that follows the electron gun.

Significant accomplishments

A high energy RF gun design was selected. The gun operates at a frequency of 2856 MHz, with a peak RF power of about 10 MW to deliver a beam of 10 MeV electrons at a current of 200 amperes and a normalized rms emittance of better than 4π mm mrad.

Extensive PIC code numerical modeling of the gun performance and dependence on various parameters such as geometry, phasing, laser spot size and more have been carried out.

A modification of the photocathode cell length has resulted in a reduction in the gun peak surface electric field of 30% and a significant linearization of the longitudinal phase space distribution.

A detailed thermal design, including 3D modeling of the gun was done. The high duty factor capability (up to 1% duty factor) necessitated advanced thermal design as well as construction of the gun from special alloys. To avoid excessive stresses of the material under the high thermal load a new material was selected (Glidcop).

Using the existing technological basis of the state-of-the-art electron guns and lasers that has been developed at BNL, the design of the gun, photocathode and microwave circuit were carried out.

Gun parts were constructed and low power RF measurements were carried out.

Assembly of the gun by brazing was started

Significant problems

Difficulties were encountered in the brazing of the Glidcop gun parts.

Industry benefits realized

Northrop-Grumman acquired knowledge in the areas of low emittance electron sources and RF gun technology. Furthermore, Northrop-Grumman acquired the manufacturing and physics design capabilities of high brightness electron sources. Presently Northrop-Grumman is the only commercial supplier of laser-photocathode RF guns, and has already produced two such systems, one of which under contract to BNL's Chemistry Department.

High brightness high duty factor electron sources will be required for the next generation of linear colliders for high energy physics research as well as for a number of commercial accelerators and Free-Electron Lasers. Commercial applications include such subjects as lithography, material testing, and medicine. Scientific applications include chemistry (in particular photochemistry of combustion dynamics, atmospheric processes such as ozone generation and depletion, greenhouse gas and acid-rain atmospheric chemistry), material science and more. The technology developed in this research may be utilized in the development of a tunable, high power UV FEL as a commercial product and in future commercial accelerators.

Laboratory benefits realized

BNL has verified its theoretical electron gun and beam transport models by the comparison with the 2 1/2 D PIC code simulations done by Northrop-Grumman. The Chemistry Department has been able to procure its accelerator system from Northrop-Grumman.

Recommended follow-on work

There is no recommended follow-on work.