# Update on the ATF Inverse Čerenkov Laser Acceleration Experiment*

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*Abstract*

The inverse Čerenkov acceleration (ICA) experiment is being performed on the Accelerator Test Facility (ATF) located at Brookhaven National Laboratory. This facility presently features a 50 MeV *e*-beam and a ~10 GW peak power $CO_2$ laser. In the experiment 1.7 atm of $H_2$ gas is used to slow the phase velocity of the light wave to match the electron velocity. The Čerenkov angle is 20 mrad and the interaction length is 20 cm. A peak energy gain of ~12 MeV is predicted assuming 5-GW of laser peak power delivered to the interaction region. An update of the experiment's progress is presented.

## I. INTRODUCTION

The Accelerator Test Facility (ATF) has been constructed at Brookhaven National Laboratory and is available for laser acceleration experiments. This new facility features a 50-MeV linac and a high peak power (~10 GW) $CO_2$ laser. The inverse Čerenkov acceleration (ICA) experiment will be the first laser acceleration experiment to use the new facility.

ICA was first demonstrated at Stanford University in 1981 [1]. The ATF ICA experiment will be investigating an improved configuration developed by Fontana and Pantell [2]. This is illustrated in Figure 1. A radially polarized laser beam [3] is focused by an axicon onto the *e*-beam inside a gas cell at the Čerenkov angle $\theta_c$ given by $\cos\theta_c = (1/n\beta)$, where $n$ is the index of refraction of the gas and $\beta$ is the ratio of electron velocity to the velocity of light. This arrangement has several advantages over the earlier Stanford experiment [2]. The ATF $CO_2$ laser has >150 times higher peak power than the Stanford laser. This will result in over 10 times more energy gain than the Stanford experiment.

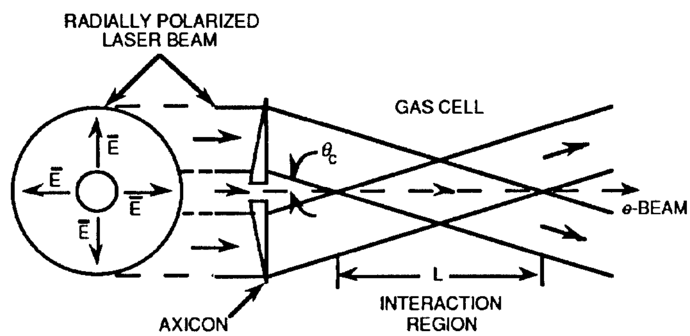


Figure 1. Basic arrangement for inverse Čerenkov acceleration.

## II. REVIEW OF MODEL PREDICTIONS

A Monte Carlo computer model of the ICA process has been developed [4] and used to predict the performance of the experiment. These predictions are shown in Figure 2. (Note, we assume a 50% efficient optical system resulting in 5 GW of peak power delivered to the interaction region.)

A peak energy gain of >12 MeV is predicted corresponding to 24% energy gain and an acceleration gradient of >60 MeV/m. Since the gain scales as the square root of the laser peak power [2], a 50-GW delivered laser beam would produce ~38 MeV energy gain and an acceleration gradient of 190 MeV/m.

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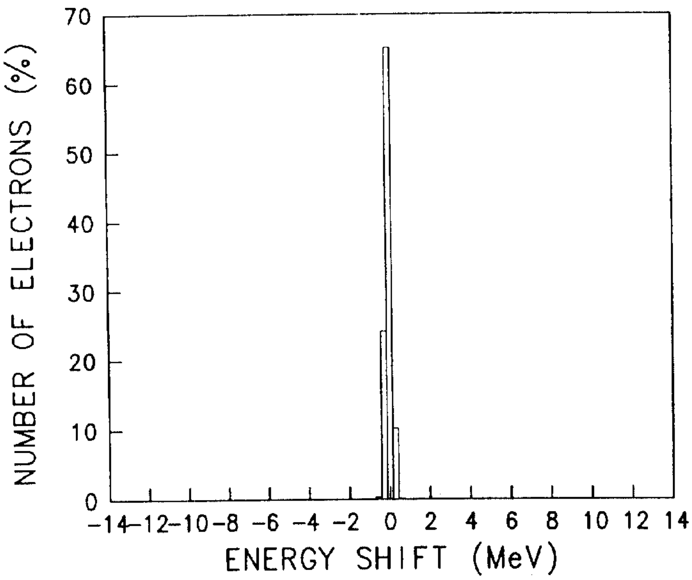
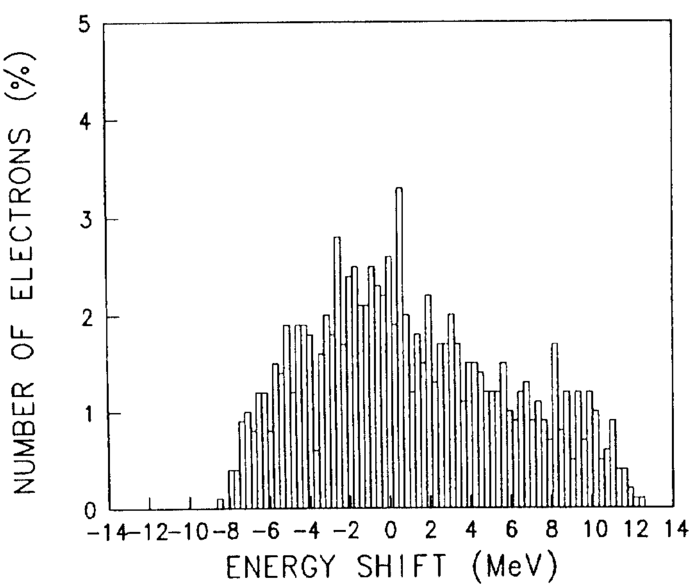
## III. DESCRIPTION OF EXPERIMENTAL APPARATUS

The experimental hardware has been fabricated and installed at the ATF. It consists of a gas cell where the ICA interaction occurs, an electron beamline system, and an optical system for converting the linearly polarized ATF $CO_2$ laser beam into one with radial polarization. Figure 3 is a schematic of the beamline system.

A schematic plan view of the internal gas cell components is given in Figure 4. An axicon mirror is used rather than a transmissive axicon (see Figure 1). The incoming laser beam enters the gas cell and reflects off a 45° mirror towards the axicon. Both the 45° mirror and axicon have a central hole for the *e*-beam to pass through. The axicon focuses the laser beam onto the *e*-beam, which enters and exits through 2.1-μm thick diamond windows sealed on the ends of the gas cell. Phosphor screens inside the cell are used to monitor the position of the *e*-beam.




(a) No Laser Present




(b) Laser Present

Figure 2. Model predictions for the ATF ICA experiment for $\theta_c$ = 20 mrad, $L$ = 20 cm, laser beam OD = 1 cm, $P$ = 1.7 atm $H_2$, *e*-beam focused to $r$ = 0.18 μm, and 2.1-μm thick diamond *e*-beam windows are used. (a) No laser present; (b) laser present at a delivered peak power of 5 GW.

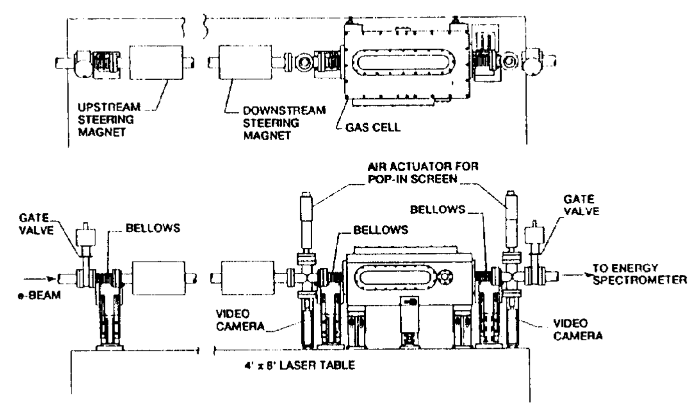



Figure 3. Schematic of ATF ICA beamline system.

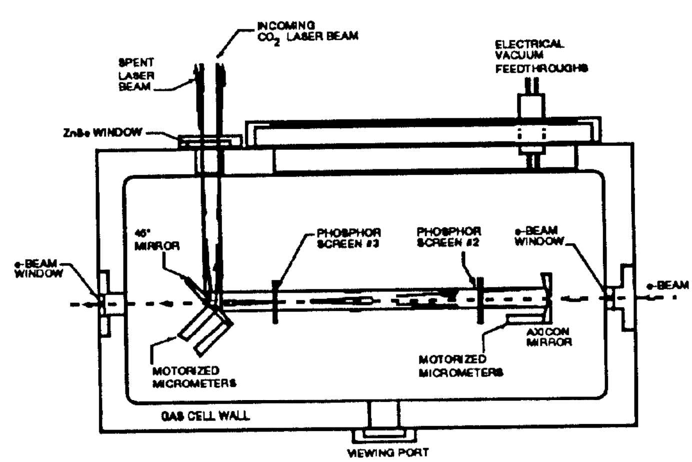



Figure 4. Schematic plan view of gas cell.

## IV. EXPERIMENT UPDATE

The experiment is divided into two phases. Phase I consisted of laser only experiments without the ATF *e*-beam, and were completed last year. During Phase I the radial polarization converter system was successfully tested with the ATF $CO_2$ laser beam. Alignment and focusing of the laser beam into the gas cell was also demonstrated. Initial investigations of any possible nonlinear effects (e.g. gas breakdown) occurring in the gas due to the presence of the high peak power laser beam proved negative. Critical optical components also passed optical damage tests, and the *e*-beam windows survived exposure to an *e*-beam provided by the National Synchrotron Light Source (NSLS).

Phase II is the actual electron acceleration experiment in which the Phase I ICA hardware is fully integrated with the ATF linac. This integration has been completed and the first Phase II experiments have begun.

At the time of this writing (May 1993), the first run with the laser and *e*-beam has been completed. The *e*-beam was successfully sent through the gas cell, including the 1-mm diameter entrance and exit diamond windows, and the 1-mm diameter holes in the axicon and 45° mirrors (see Figure 4). Approximately 4 GW of laser peak power was delivered to the interaction region.

This first run revealed several modifications to the experimental system that need to be implemented. First, the system devised to view the positions of the *e*-beam and laser beam within the gas cell needs to be improved. This is important to ensure the physical overlap of the beams within the gas cell. Second, the high power laser beam tends to damage the 45° mirror and axicon around the holes in their centers. This is because the radially polarized beam is not purely annular in shape and a significant amount of laser energy strikes the edges of the holes.

## V. FUTURE WORK

Modifications to the experimental system will be made before the second run to rectify the problems encountered during the first run. We expect to observed acceleration of electrons within the next several months.

## VI. REFERENCES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