NRL LASER FUSION PROGRAM
May-June 2002 Bimonthly Highlights

Efficient Electron Beam Deposition For Repetitively Pulsed Krypton Fluoride Lasers

Electra is a repetitively pulsed, electron beam pumped Krypton Fluoride (KrF) laser that is developing the technologies that can meet the Inertial Fusion Energy (IFE) requirements for durability, efficiency, and cost. The technologies developed on Electra will be directly scalable to a full size fusion power plant beam line. One of the components currently investigated is a long life, transparent pressure foil structure (hibachi) that allows efficient energy deposition into the laser gas.

High energy deposition efficiency was achieved with two innovations: 1) eliminating the anode foil on the diode side of the hibachi structure, and 2) patterning the electron emitter into strips so the beam "misses" the hibachi ribs (see Fig. 1). While these are conceptually simple, they are difficult in practice: Eliminating the anode results in highly non-uniform electric fields in the A-K gap of the vacuum diode, and the beam rotates and shears due to its interaction with the applied axial magnetic field of 1.4 kG that is used to guide the e-beam into the laser cell.

Two types of cathodes have been evaluated: (a) a monolithic 27 x 97 cm^2 cathode at an A-K gap of 42 mm and (b) a strip cathode; 24 strips, each 25 mm x 27 cm, at an A-K gap of 37.5 mm (see Table 1). The deposited energy was obtained from a Baratron that measures the pressure rise in the laser cell. The results include the flat-top portion as well as rise and fall times of the e-beam pulse. 1-D simulations that do not include the hibachi ribs (e.g., by modeling only the pressure foil and the laser gas) predict the theoretical deposition efficiency limit without e-beam losses due to the hibachi.

Table 1. E-beam energy deposition efficiency at 500 kV, 1.2 atm. of Kr, and a 50 μm thick Ti pressure foil.

	Efficiency for the entire pulse	Efficiency for flat-top portion only
Monolithic cathode	47%	53%
Strip cathode	62%	67%
Simulations without hibachi ribs	67%	72%

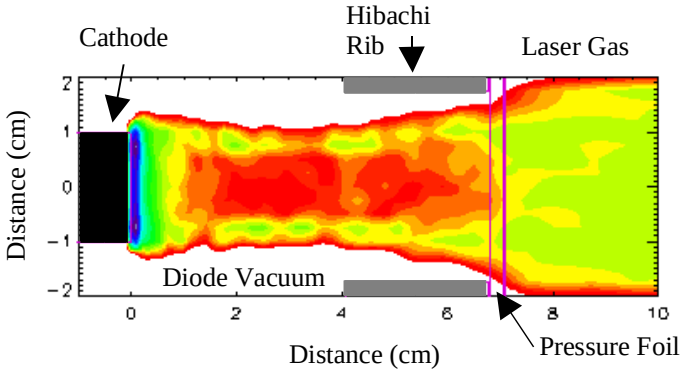

Figure 1: Simulation of an electron beam that propagates from a 2 cm wide cathode strip through the A-K vacuum gap, hibachi structure, pressure foil into the laser gas. The electron number density is shown in false colors.

The experimental results of diode voltage vs. Ti pressure foil thickness are summarized in Table 2. 3-D Large Scale Plasma (LSP) simulations, which include the actual diode geometry, external magnetic field, hibachi ribs, and backscattering, showed that an energy deposition efficiency of 74% for a 500 keV beam and a 25 μm thick Ti pressure foil. These results agrees well with the experimental observation of 75% (see Table 2).

To achieve even higher deposition efficiencies, a new hibachi with shallower ribs has been constructed. It should create a more uniform electric field at the anode, and thus, minimize e-beam spreading losses. Preliminary simulations showed that the ultimate goal of >80% hibachi efficiency is achievable in a full-scale (750 keV) system.

Table 2. Flat-top e-beam energy deposition efficiency with a strip cathode at 400-500 kV and 25-50 μm thick Ti pressure foils.

Diode voltage	Flat-top efficiency with 50 μm thick Ti pressure foil	Flat-top efficiency with 25 μm thick Ti pressure foil
400 kV	57%	71%
500 kV	67%	75%