DEVELOPMENT OF A 402.5 MHZ 140 KW INDUCTIVE OUTPUT TUBE

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Abstract

This paper describes a 402.5 MHz 140 kW Inductive Output Tube (IOT) that is being developed for use in proton accelerators. New, more efficient, computer codes will be used to simulate the time dependent behavior of the IOT. The principal components of the device, including the RF structure, electron gun, and magnetics are described.

Calabazas Creek Research Inc. (CCR) is developing a pulsed 140 kW, 402.5 MHz Inductive Output Tube (IOT) for use in proton accelerators. Unlike multiple-beam IOT's currently under development, this device will use a single electron beam, and will be less expensive and have a higher reliability. A conceptual drawing of the IOT is shown in Figure 1.

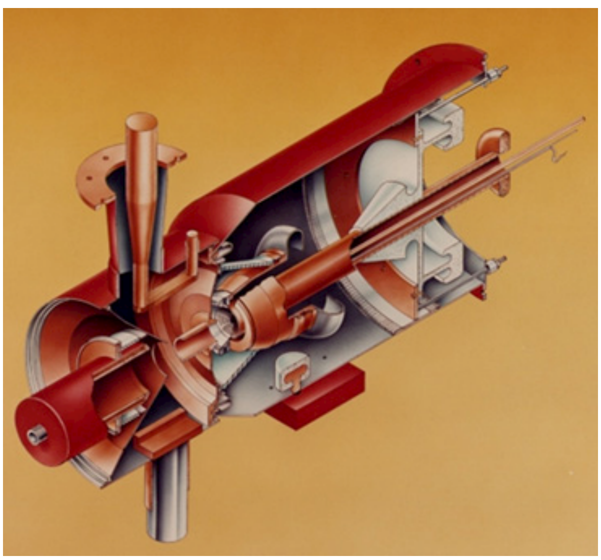

Figure 1: Conceptual drawing of the IOT.

The program includes the use of new design tools, including NEMESIS, TESLA and a version of CCR's 3D Beam Optics Analysis (BOA) code modified to enable time dependent modeling. The design includes the electron gun, collector, input and output cavities, input and output couplers and the RF output window. An emphasis is being placed on the electron gun, which will as usual include a grid for the high frequency modulation, and the input cavity.

BOA is already capable of modeling guns with complex grids. Output from BOA showing the trajectories from an equilibrium solution of an IOT gridded gun is shown in Figures 2 and 3.

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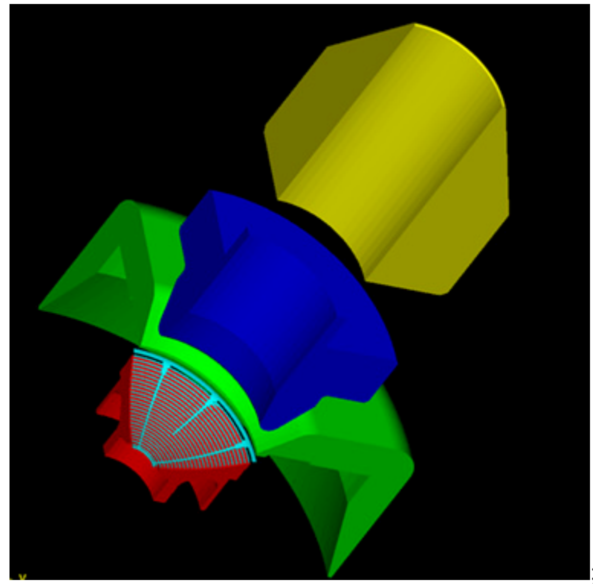

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Figure 2: Model of an IOT gun and output cavity region, as used in BOA.

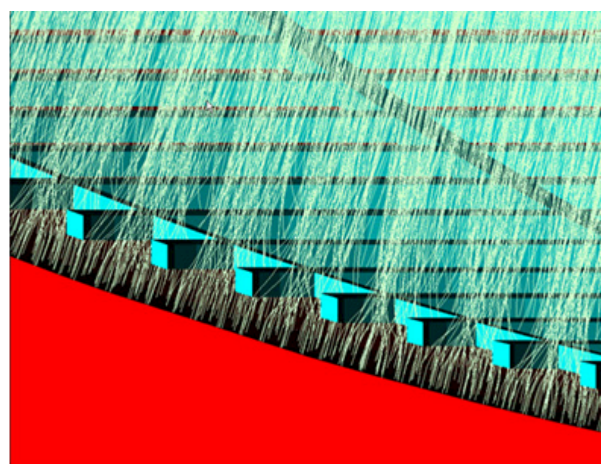

Figure 3: Beam trajectories of the gridded gun shown in Fig. 2.

As part of initial testing, the new version of BOA was used to model an electron gun with a mod-anode without RF modulation. Figure 4 shows particles in two time steps: 50th and 100th respectively. This type of temporal particle-in-cell simulation requires all particles are pushed synchronically. At the beginning of each time step, particles are continuously emitted from the cathode and then pushed together with existing ones.

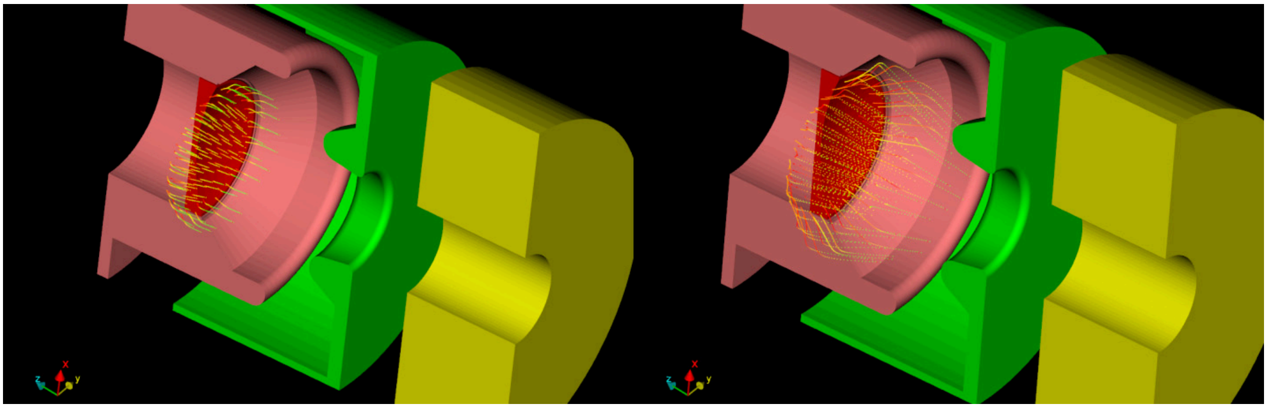

Figure 4: Model of an IOT gun and output cavity region, as used in BOA.

HFSS, TESLA [1] and NEMESIS [2] are being used for design of the input cavity. NEMESIS is a time-domain formulation that relies on integration of equivalent circuit equations coupled with the Lorentz force equations for particle trajectories. The code currently employs a 2D model for the circuit fields and a 2D Poisson solver. TESLA is an advanced circuit simulation code for klystrons and similar RF devices. It uses the telegrapher's equations to calculate the electron beam-RF wave interaction on the time scale of the change of the RF fields. The fields in the drift tube are calculated self-consistently with the fields at the cavity gaps.

The current effort is to use the output of BOA as the beam for TESLA. Initial studies are being performed using the pulse shape derived from the BOA-generated beam. The pulse shape generated by BOA is shown in Figure 5. TESLA converts this into a train of identical pulses. A plot showing the evolution of the pulses as they propagate along the klystron drift section, with the RF suppressed is shown in 6. This shows clearly the spreading of the bunches due to space charge.

With this same beam, but with the RF interaction taken into account, TESLA predicts the output power shown in Figure 7. The efficiency is 58%. This is very low for an IOT, but no optimization was attempted for this example, and it is expected that > 70% efficiencies more typical for IOT's will be achieved with further effort.

REFERENCES

[1] S.J. Cook, et al., "Validation of the Large-Signal Klystron Simulation Code TESLA," IEEE Transactions on Plasma Science, Vol. 32, Issue 3, pp. 1136-1146, June 2004.

[2] H. P. Freund, W. H. Miner, Jr., J. Verboncoeur, Yanxia Li, and E. Wright, "Time-Domain Simulation of Inductive Output Tubes," IEEE Transactions On Plasma Science, Vol. 35, No. 4, p. 1081, August 2007.

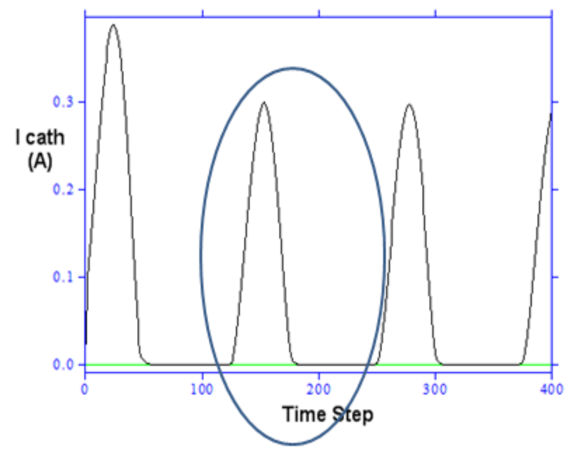

Figure 5: Portion of a pulse train generated by BOA. The center pulse was used as input for TESLA.

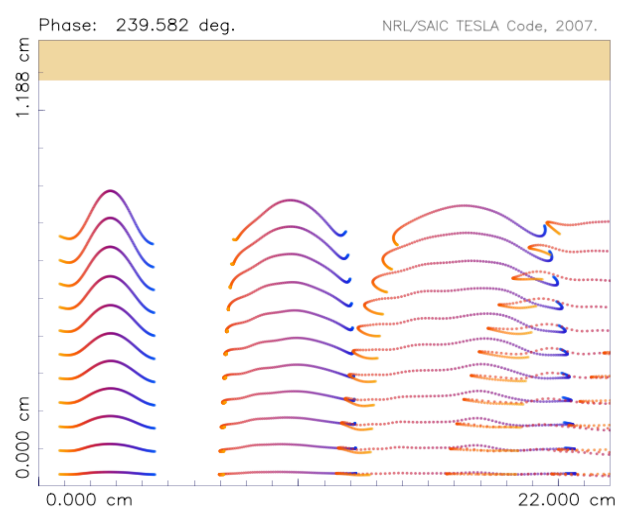

Figure 6: Evolution of pulses propagating along the drift region, as predicted by TESLA.

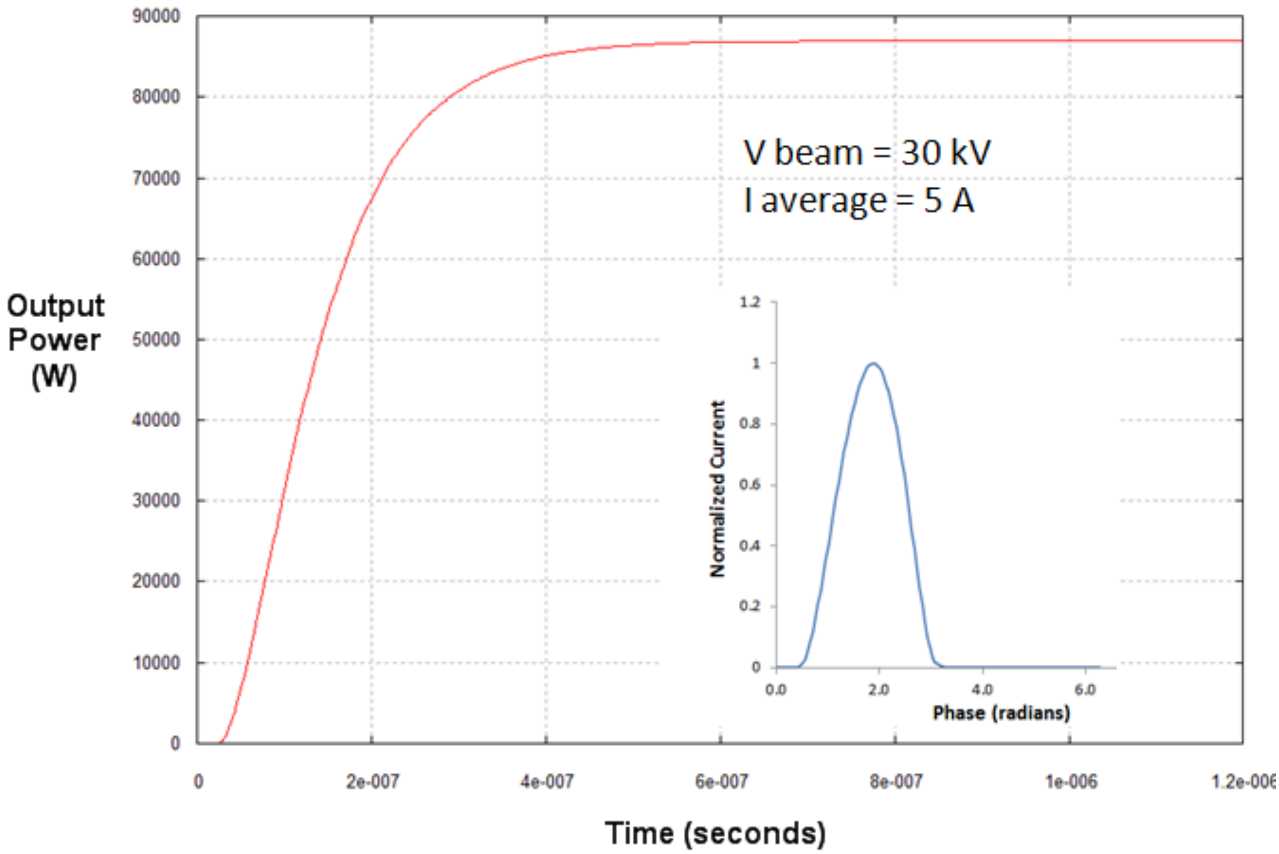

Figure 7: Output power as a function of time, as predicted by TESLA with a current pulse shape from BOA.