MAGIC-2D Simulations of High Efficiency Hollow Beam Klystrons

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Abstract:

Results from MAGIC-2D simulations of hollow beam, 800 MHz klystrons, with efficiencies on the order of 85% are presented. Such tubes employ the core oscillation method of electron bunching, which allows for most electrons in the beam to be contained within the bunch at the output cavity. By moving towards hollow beam geometries, the bunch at the output cavity presents a favourable phase and spatial profile for energy extraction, and thus, the overall tube efficiency can be maximised.

Introduction:

Upcoming large scale particle accelerators, such as the Future Circular Collider (FCC) [1] and the Compact Linear Collider (CLIC) [2] require significant amounts of RF drive power, on the order of 100 MW. As a result, the efficiency of the RF source is of prime importance. Klystrons are an attractive RF drive for such accelerators, with state-of-the-art tubes having efficiencies of up to ~70% [3].

One of the limiting factors for a klystrons' efficiency lies with the bunch shape. To ensure maximum energy is extracted from an electron bunch to the output RF signal, the phase and spatial profile of the bunch should be such that after being decelerated at the output cavity, each particle in the bunch has identical velocity. The core-oscillation method (COM) of electron bunching [4,5] allows the core of the bunch to expand due to space charge forces between subsequent cavities, allowing outlying electrons to be brought into the bunch monotonically. While COM results in a klystron of increased length, their efficiencies are predicted to approach 90%, as almost all particles exist with a bunch when they approach the output cavity.

It has previously been predicted with MAGIC-2D [6], that efficiencies of up to 83% can be obtained, for devices employing solid electron beams and utilising the COM method. In these simulations, the velocity profile of the spent beam was seen to vary with beam radius, resulting in stratification of the beam. By moving to a hollow beam, it is postulated that this stratification can be reduced. MAGIC-2D simulations of such hollow beam klystrons will be discussed.

Numerical simulations:

For an electron beam of ~133 kV, 12.5 A, an eight cavity klystron has predicted an output power of ~1.45 MW, corresponding to an efficiency of 86% (as seen in Fig. 1a). The spatial profile of the electron beam is seen in Fig. 1b; here, the evolution of the bunch can be seen as it progresses along the drift tube. As can be seen, some particles lag the bunch at the final cavity, indicating the potential for the efficiency to be improved upon further.

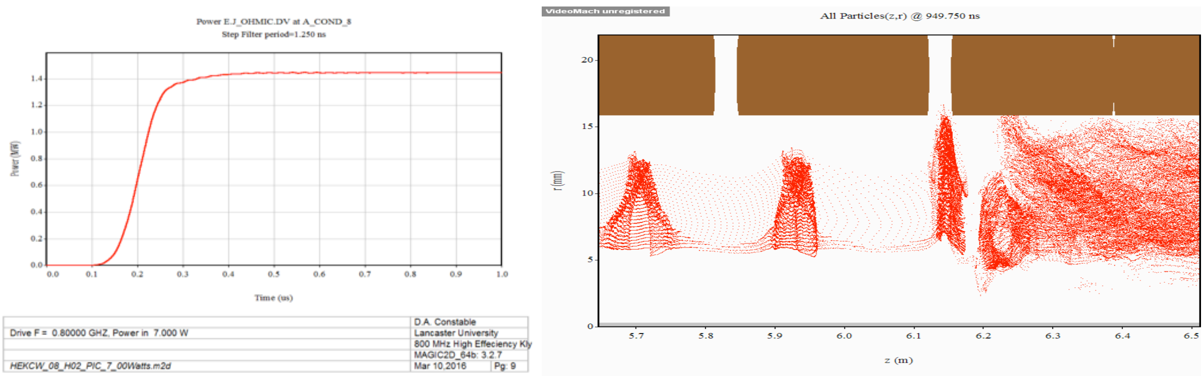

Fig. 1 MAGIC-2D results of a hollow beam klystron, showing a) output power, and b) RZ profile at the final two cavities.

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References:

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