Compact 1.3 GHz, 3MW, low-voltage Multi-Beam Klystron

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The research reported here was aimed at development of an L-band multi-beam klystron with parameters relevant for ILC. The chief distinction of this tube from MBKs already developed for ILC is its low operating voltage of 60 kV, a virtue that implies considerable technological simplifications in the accelerator complex. To demonstrate the concept underlying the tube's design, a six-beamlet quadrant (a 54″ high one-quarter portion of the full 1.3 GHz tube) was built and recently underwent initial tests, with main goals of demonstrating rated gun perveance, rated gain, and at least one-quarter—that is 2.5 MW—of the full rated power. These tests, with 10-15 µs RF pulses, produced output powers of up to 2.86 MW at an operating voltage of 60 kV with 56 dB gain and high efficiency, and showed acceptably small beam interception. Therefore, the klystron has already achieved more than its design output-power at 60 kV, albeit in short pulses. Our initial three-day conditioning campaign without RF drive (140 µs pulses at a 60 Hz repetition rate) was stopped at 53% of full rated duty because of time limits at the test-site; no signs appeared that would seem to prevent achieving full duty operation (i.e., 1.6 ms pulses at a 10 Hz repetition rate). Additional tests are required and are currently planned to commence by the end of 2015 using facilities being installed in the Yale University Beam Physics Laboratory.

Figure 1 shows a cut-away view of the tube, a photo of the tube itself, and a photo of it during installation in the test site at CPI. Details of the tube design have already been published elsewhere. Tube tests were performed with 10-15 µs RF-pulses centered within a wider gun pulse, as shown in Figs 2 and 3. The highest gun voltage was 66 kV. The perveance was found to be 5.5×10^{-6} A-$V^{-3/2}$ for voltages between 40 and 66 kV—somewhat higher than the design value of 4.9×10^{-6} A-$V^{-3/2}$. The body intercept as a percentage of beam-power, inferred from heat deposition on the klystron body, was found to be as low as 6.5 to 7% with RF applied, as shown in Fig 2 (right). This figure requires further analysis, to account for heat transfer between different portions of the tube and for Ohmic losses in the RF structure. With an achieved power output at 60 kV as high as 2.86 MW, the klystron efficiency approached 59%, but with a body intercept current above 7%. With body intercept current below 7%, the observed efficiency at 60 kV was 55% (2.67 MW output). At present, the trade-off between intercepted current and efficiency is unclear, so further studies and conditioning are needed.

Figure 4 demonstrates a family of curves showing the dependences of the Output-power vs the RF frequency for different coil settings. This exercise led, in particular, to obtaining the "optimized 1" coil set (see Fig 3, point #1). Figure 5 shows an example of a family of transfer curves for the coil settings (Optimized 1) that minimized or nearly minimized the body-interception, and improved the bell-jar shape presented before by the red curve on the left hand-side. One observes that, in particular, @ 59kV, a reasonably smooth transfer curve results starting at 2W - 2.5W of the drive power. At the same time, 2.5 MW or even more MWs are achievable once the drive power > 5 W, bringing the performance (power-wise) above the design specs.

Acknowledgements:

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References:

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3. J. L. Hirshfield, Principal Investigator, *Omega-P, Inc. Final Report*, "RF Cavity Chain and Magnetic Circuit for a 10-MW, 1.3-GHz, Low-Volatge Multi-Beam Klystron", based on efforts under Phase II grant DE-SC0000927, prepared by Dr. Hirshfield, tel: (203) 789-1164, e-mail: jay@omega-p.com

Figure1. (Left) a 3-D cut-away view of the tube; **(center)** photo showing the tube before it was inserted the magnet assembly; and **(right)** the test-setup, showing the klystron (in blue magnet), RF-window, and RF-load, during installation at the CPI test site

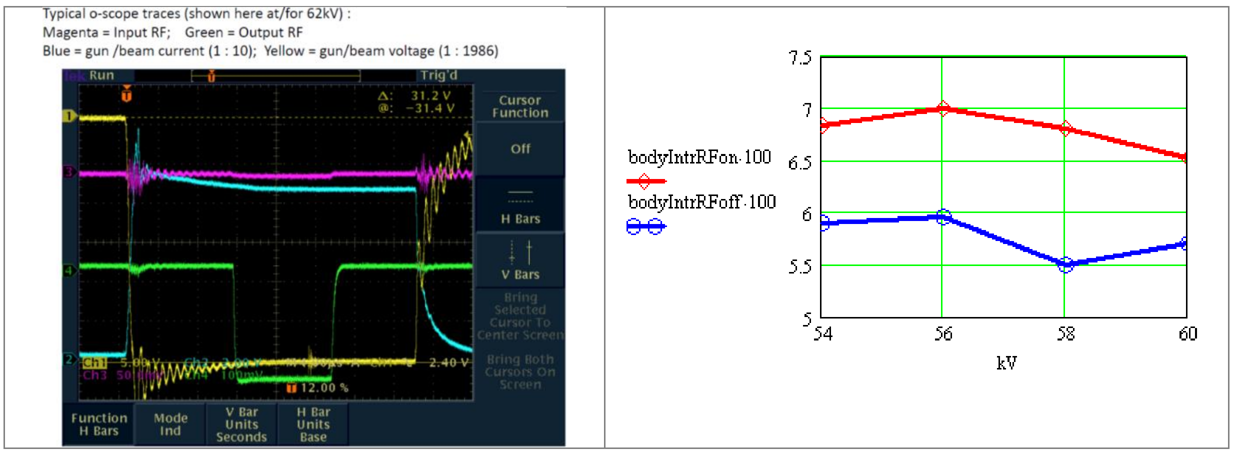

Figure 2. (Left) Traces of gun voltage (yellow); beam current (blue), output power (green), and input power (magenta); the horizontal scale is 5 micro-secs per div. **(Right)**: Inferred body intercept measured as a percentage of beam-power with RF on (red) and off (blue)

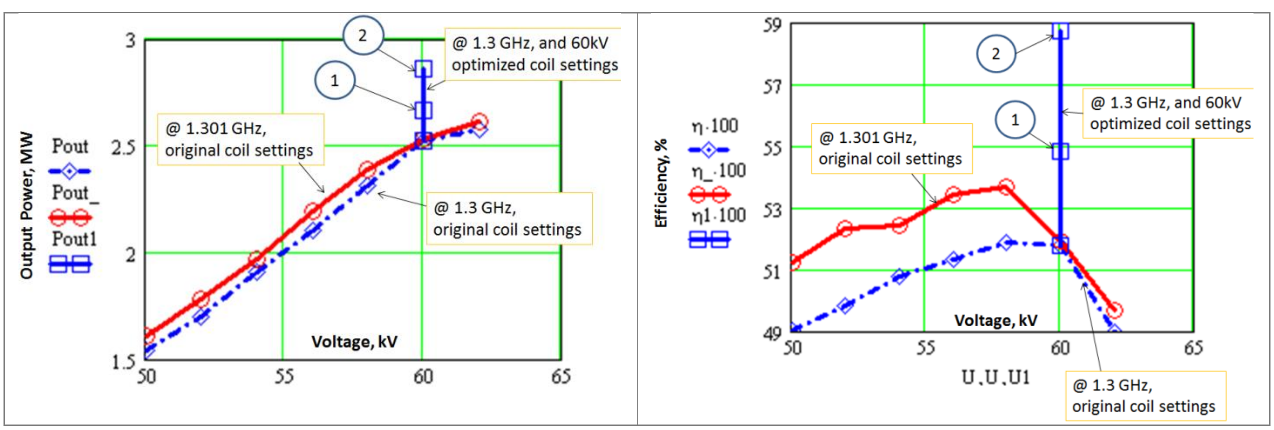

Figure 3. (**Left)** output power (MW) *vs* beam voltage (kV) at 1.300 GHz and 1.301 GHz,
as measured via calorimetry on the matched load. **(Right)** Efficiency as a percentage of beam-power. The currents in matching and focusing coils were optimized to obtain higher output powers as shown by points 1 and 2

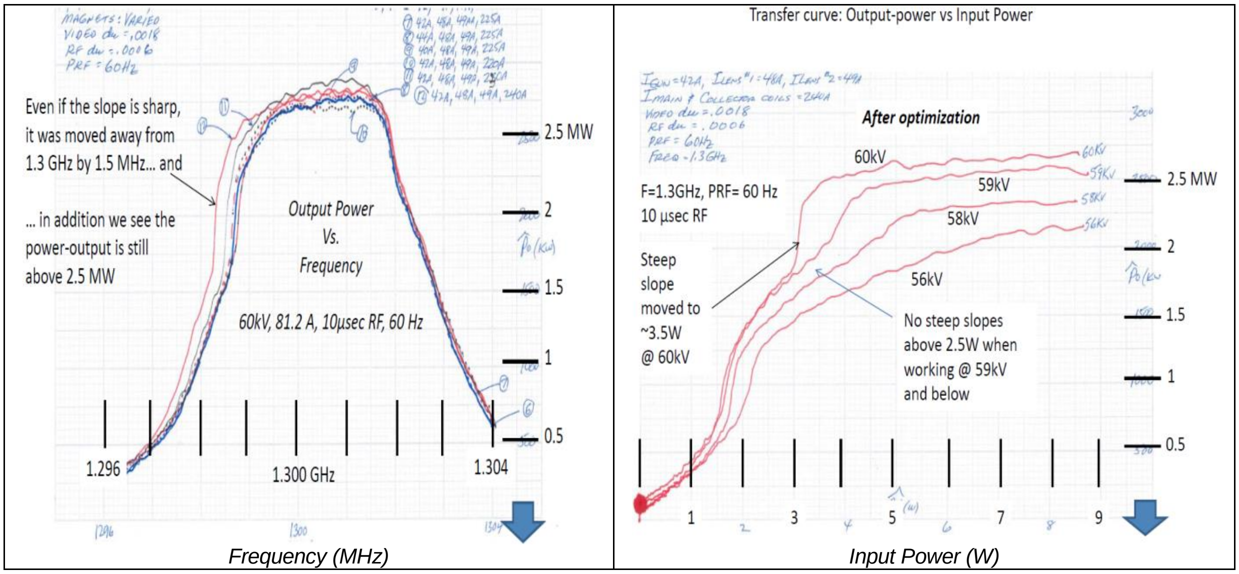

Figure 4 (left) example of investigations of the bell-jar shape of the dependence of the Output-power vs. the RF frequency at 60kV vs. different coil settings. **Figure 5 (right)** An example of a family of transfer curves for the coil settings that minimized the body-interception. [Input power is in Watts (horizontal axis)]. The coils are set to "Optimized 1" (see Fig.3)