20.2: Testing of the Omniguide Traveling-Wave Tube

Dmitry Yu. Shchegolkov, Lawrence M. Earley, W. Brian Haynes, Richard M. Renneke, Evgenya I. Smirnova, and Nikolai A. Yampolsky
Los Alamos National Laboratory
Los Alamos, New Mexico, USA, 87545
d_shcheg@lanl.gov

Abstract: *We have designed, fabricated and tested with low power a novel W-band TWT based on a slow-wave cylindrically-symmetric PBG dielectric structure, or an "omniguide". PBG TWT structures have great potential for very large bandwidth and linear dispersion. A gain experiment is under way at Los Alamos with the structure being driven by a 2 A, 110 kV electron beam. In this presentation we will report the design of the omniguide TWT structure, theoretical computations of the gain and the results of S-parameters measurements. We will also describe the electron beam test stand setup and report first results from the gain measurement experiment.*

Keywords: photonic band gap structure, dielectric traveling-wave tube, W-band.

Introduction

Compact, efficient, high-bandwidth and high-power mm-wave sources are essential for many applications in secure communications, radio astronomy, environmental monitoring, imaging, and spectroscopy for remote sensing in nonproliferation [1]. Commercial microwave tube amplifiers are available at frequencies up to only 100 GHz (W-band) and have to trade off maximum output power against bandwidth. A wide-band mm-wave traveling-wave tube (TWT) amplifier development is underway at Los Alamos National Laboratory [2]. A previously developed vane-loaded waveguide TWT has demonstrated 7 percent bandwidth. We propose to use photonic band gap (PBG) structures for constructing a TWT with a much wider bandwidth operating at around 100 GHz, a completely novel approach [3].

Results

The omniguide [4] represents a periodic system of concentric dielectric tubes, which can effectively confine a TM_{01}-like mode near the axis (Fig. 1a, b). The omniguide structure was assembled of fused silica cylinders mounted in between two copper waveguide input and output holders (Fig. 1c, d). The structure was cold-tested and the results were found to be in excellent agreement with the design [3]. The low power transmission test demonstrated low internal loss and a wide operation band for the omniguide (Fig. 2). Theoretical studies of net gain yielded ≈4 dB/cm for a 2 A, 110 kV electron beam (Fig. 3). We have been working on the electron beam setup described in [2] to fine-tune it for the high-power omniguide gain experiment.

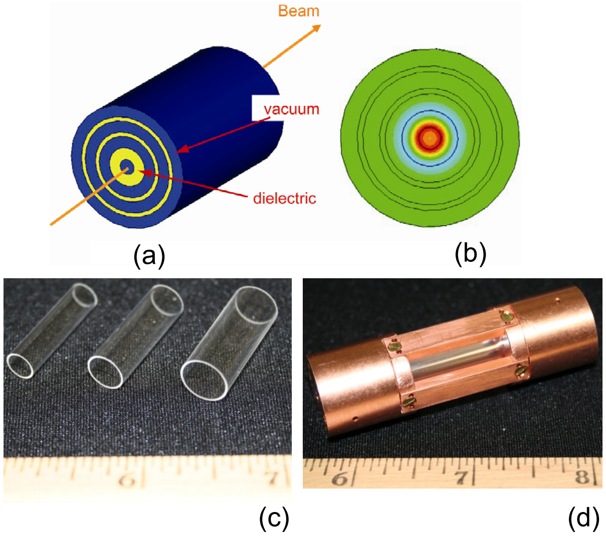

Figure 1. The schematic of an omniguide, the blue area is vacuum and the yellow area is dielectric (a); the longitudinal electric field magnitude in the TM01-like mode of an omniguide computed with Microwave Studio [5] (b). Photographs of the silica tubes (c) and the assembled omniguide TWT structure (d).

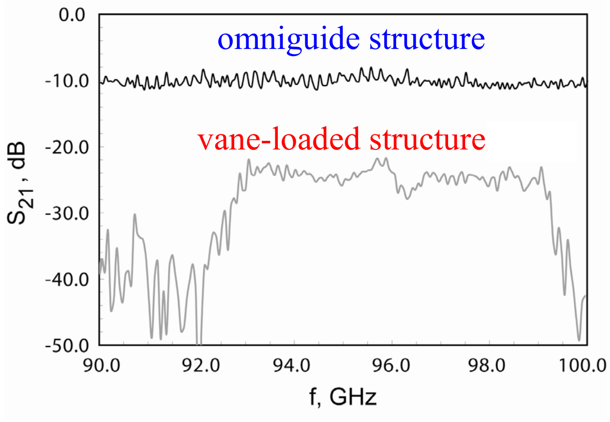

Figure 2. Comparison of the transmission through the omniguide TWT to the transmission through the vane-loaded TWT of [2].

The first omniguide gain experiments with low input power at 94 GHz demonstrated that the quality and the alignment of the electron beam were not adequate and we were unable to pass 2 A current at the optimum voltage through the active region. We only observed the transmission of 0.5 A of beam current at approximately 125 kV for 100 – 200 ns through the structure. While the maximum gain at 94 GHz occurs between 110 and 115 kV, nevertheless we still observed gain with the current setup. However, the gain was limited to 2 dB (Fig. 4), which accurately matches theoretical predictions for the current of 0.5 A.

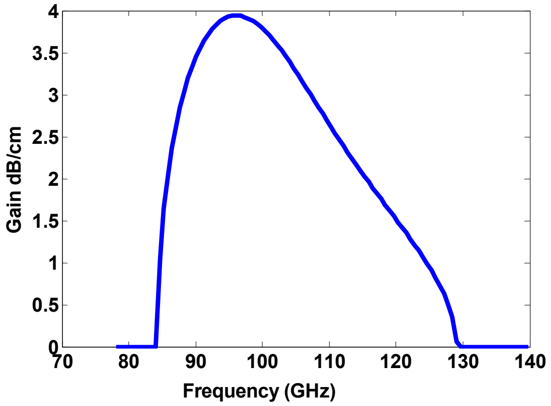

Figure 3. Net gain in the omniguide TWT driven by a 1.0 mm diameter, 2 A, 110 kV electron beam.

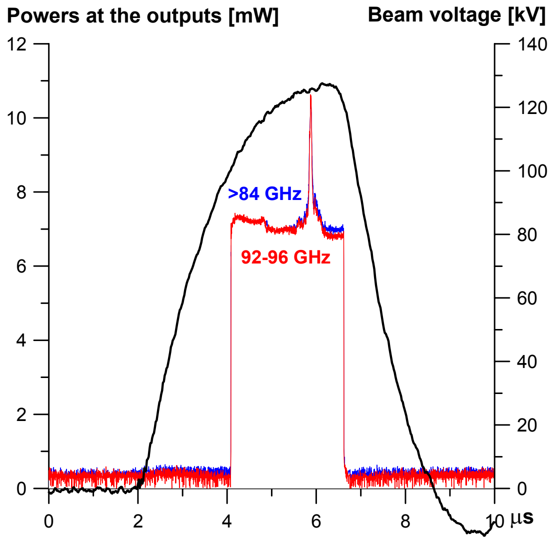

Figure 4. Measured output powers from the omniguide after different frequency filters. About 2 dB of gain is observed at approximately 6 µs.

The omniguide structure was pulled out from the beamline, disassembled and inspected. Beam tracks were detected on the inner side of the smallest silica tube (Fig. 5), indicating that some portion of the beam was intercepted by the silica structure inside of the omniguide. Presently, the work is underway to improve the beam alignment.

In conclusion, we demonstrated the transmission of high-current electron beam through the omniguide structure. Silica structure was not damaged by the beam and gain was observed. This result is of great significance, since dielectric omniguide TWTs have many advantages over metal tubes. Compared to metallic structures, dielectric structures confine modes with smaller losses and higher breakdown limits, they have wider frequency bands of operation (20% or more), and they have linear dispersion relations which offer high interaction impedance over a wide bandwidth. Furthermore, fabrication of these structures is potentially cheaper, easier, and faster than metallic TWTs, which enhances the commercial possibilities of this technology.

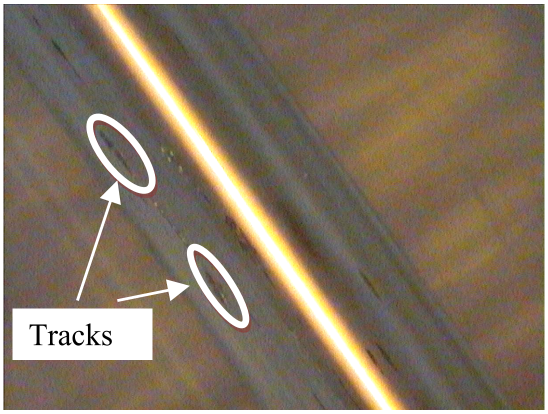

Figure 5. Electron beam tracks on the inner side of the central silica tube of the omniguide (photograph made with microscope).

Acknowledgements

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