Terahertz Backward Wave Oscillator Development

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Calabazas Creek Research, Inc. is funded by the National Aeronautics and Space Administration to develop efficient, light-weight, backward wave oscillators (BWOs) for applications from 300 GHz to more than 1 THz. These devices are needed as local oscillator (LO) sources in heterodyne receivers. Very low noise heterodyne receivers are needed at submillimeter wavelengths for low-background radioastronomy observations and remote sensing of comets, Earth and other planetary atmospheres. Important molecules play a key role in the energy balance, chemistry, and dynamics of interstellar molecular clouds, planetary atmospheres, and cometary coma. High resolution observations of these species are needed to understand the structure and evolution of the galactic and nearby extragalactic interstellar medium. Heterodyne instruments are required for these observations at ground-based observatories such as the Caltech Submillimeter Observatory, airborne observatories such as the upcoming NASA SOFIA (a 747 aircraft with a 2.5 m telescope), and the ESA Far Infrared and Submillimeter Telescope mission. Currently there are no compact, low- power, broadband LO sources, even above a few hundred GHz. Such a source would enable new science missions and enhance the science return of a given mission as well as expedite the laboratory development of the receiver system. Above 100 GHz, only BWOs have broad tunability (over 100 GHz) and high output power (~1 mW); however, existing BWOs are heavy (over 20 kg), consume a lot of power (270 W), require water cooling, and have poor output mode purity.

The technical objectives of the current program are as follows:

- Utilize advanced manufacturing techniques to extend the operating range to frequencies exceeding 1 THz.
- Incorporate a depressed collector to improve the efficiency and eliminate water cooling,
- Improve the output coupling to increase coupling efficiency and mode purity,
- Reduce the magnet system size and weight.

Previous presentations described the design of the 600-700 GHz BWO[1]. The prototype is currently being assembled by CCR and RWI. A number of issues arose during the construction of components that required significant technological development.

Circuit: The slow wave circuit requires creation of 1500 metallic "towers," or pintles, that are 30 microns by 20 microns in cross section and 80 microns high. These are separated by approximately 20 microns. Machining these structures presented a significant challenge, so two separate approaches were undertaken. CCR worked with Sandia National Laboratory to develop a lithographic process using LIGA; which could provide mass production of slow wave circuits up to 1.5 THz. This development proved more difficult than anticipated due to a number of processing steps. Never the less, Sandia was able to solve most problems and accurately expose and electroplate the desired structures. Unfortunately, the wafer failed to complete the final process successfully. Additional funding was provided to continue this development, and Sandia is continuing this research. This development will be crucial to increase frequencies above 1 THz.

In parallel, RWI successfully implemented advanced electric discharge machining (EDM) procedures using 8 micron wire. This allowed machining of the structures with the required accuracy, so four circuits are currently being produced. RWI is investing in more advanced equipment to manufacture even smaller structures.

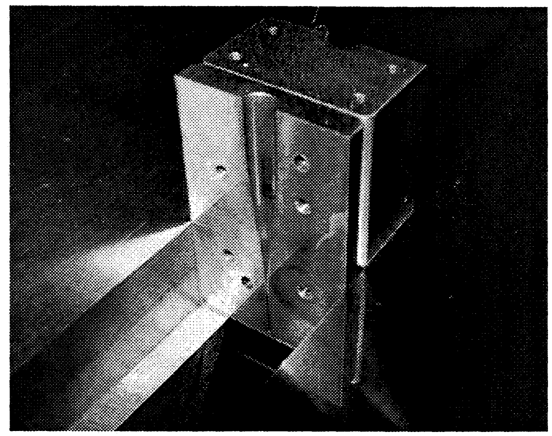

FIGURE 1. Body half with output waveguide system

Output Waveguide System: The BWOs incorporate fundamental waveguide coupling from the slow wave structure, transitioning to a Gaussian mode antenna for coupling to external devices. The system requires manufacture of the BWO body in halves to incorporate the matching structures, which contain 2 micron features. RWI developed special procedures to manufacture these structures, which were successfully tested at the Jet Propulsion Laboratory. A photograph of one half the 600-700 GHz body is shown in Figure 1.

Window: Initially, the program planned to use RF windows manufactured by Istok Company, the original developer of the BWOs; however, the thickness was not appropriate for the advanced output waveguide system. Consequently, CCR developed a procedure for manufacturing the 100 micron thick windows using sapphire ceramics. Because of the small window thickness, special brazing and lapping procedures were developed to make the window assemblies. A solid model of the window assembly is shown in Figure 2.

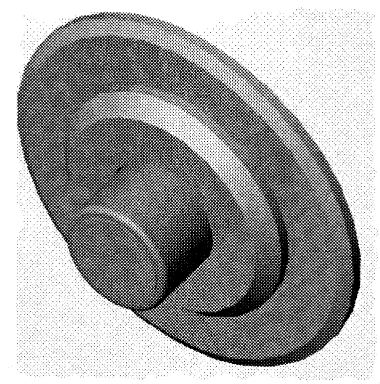

FIGURE 2. Solid model of window assembly

Depressed collector: A important feature of the BWO is the depressed collector. Successful implementation will significantly increase the operating efficiency and eliminate the current requirement for water cooling. Special adhesives were investigated for connecting the ceramic insulator to the body section for conductive cooling. Components of the collector are shown in Figure 3.

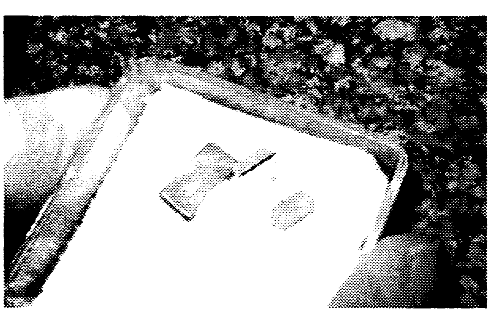

FIGURE 3. Metal components of the depressed collector

1. Lawrence Ives, Jeff Neilson, Malcom Caplan, Carol Kory, David Marsden, "Advanced Terahertz Backward Wave Oscillators," International Vacuum Electronics Conference, Monterey California, June 2002

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