01 February 1999

DTIC-OCP
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Dear Madam/Sir:

Per contractual requirements I am enclosing two copies of a final technical report on AFOSR Grant F49620-96-1-0379, both with a completed SF-298.

Thanks for your assistance with this matter.

Sincerely,

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A Versatile High-Power Laser System for High Spatial Resolution Nanosecond Plasma Diagnostics in Electron-Beam Driven High Power Microwave Sources

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Abstract:
The purpose of the acquired instrumentation was to perform high spatial resolution and nanosecond time resolution plasma diagnostics in intense electron beam-driven high power microwave (HPM) sources to better understand the "pulse shortening" problem. We have thus performed the first laser interferometry measurement inside a high power backward wave oscillator (or any other intense beam-driven HPM source for that matter) during the course of microwave generation reported in the literature. Line-integrated electron densities between $9 \times 10^{15}$ and $2 \times 10^{16}/cm^2$ for microwave powers between 20 and 120 MW have been measured. The two main sources of the measured electron density are postulated to be i) plasma generated from the cutoff neck due to beam scrape off and, ii) material removed and ionized from the slow wave structure walls during microwave generation. A catastrophic microwave discharge results in termination of subsequent microwave generation. Novel modifications to the inlet of the slow wave structure in intense beam-driven backward wave oscillators are suggested as a result of this research.

Subject Terms:
High Power Microwaves (HPM), Pulse Shortening, Plasma Diagnostics, Laser Interferometry
The University of New Mexico
Pulsed Power and Plasma Science Laboratory

DURIP-96 FINAL REPORT

A Versatile High-Power Laser System for High Spatial Resolution Nanosecond Plasma Diagnostic in Electron-Beam Driven HPM Sources
(Grant No. F49620-96-1-0379)

01 February 1999

Submitted by:

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Abstract

This final report describes the acquisition and implementation of instrumentation purchased under the auspices of the FY'96 DURIP program. All of the laser and optical instrumentation have been purchased, installed, and used to measure plasma during the course of microwave generation in a high power backward wave oscillator (BWO) experiment. The results of this measurement have been documented in a journal publication that was included in the appendix of the Technical Progress Report dated 5 August 1998. The one outstanding acquisition as of the most recent progress report was the “educational reltron” high power microwave (HPM) source that was designed in conjunction with Titan Advanced Innovative Technologies (Albuquerque, NM). This final item was delivered in January 1999 and is now undergoing initial trials. It is anticipated that the educational reltron source will be utilized in classroom instruction at the graduate level in the 1999-2000 academic year.

The purpose of the acquired instrumentation was to perform high spatial resolution and nanosecond time resolution plasma diagnostics in intense electron beam-driven high power microwave (HPM) sources to better understand the “pulse shortening” problem. We have thus performed the first laser interferometry measurement inside a high power backward wave oscillator (or any other intense beam-driven HPM source for that matter) during the course of microwave generation reported in the literature. Line-integrated electron densities between $9 \times 10^{15}$ and $2 \times 10^{16}/\text{cm}^2$ for radiated microwave powers between 20 and 120 MW have been measured. The two main sources of the measured electron density are postulated to be i) plasma generated from the cutoff neck due to beam scrape off and, ii) material removed and ionized from the slow wave structure walls during microwave generation. A catastrophic microwave discharge results in termination of subsequent microwave generation.
Description of Instrumentation

The instrumentation that was proposed to purchase were:

1. Coherent Inc. Infinity Pulsed Nd:YAG Laser System (this has been purchased, installed and used in our laboratory).
2. Burleigh Inc. PLSA Pulsed Laser Spectrum Analyzer and computer for operation (this has been purchased, installed, and used in our laboratory).
3. Newport Corp. optical workstation, components, and projects kits for educational component of award (this has been purchased, installed, and used in our laboratory).
4. Titan Advanced Innovative Technologies Educational Reltron High Power Microwave Source. (This has been constructed, delivered, and installed in the University of New Mexico EECE Department’s Pulsed Power and Plasma Science Laboratory.)

Photographs of the equipment described above (excluding the reltron source) can be found at our website www.eece.unm.edu/muri98/punm1.htm and subsequent images. The balance sheet indicating the instrumentation acquisition dates is presented below.
Laser interferometry is used for the first time to measure plasma electron density along the slow wave structure (SWS) wall during microwave generation in a vacuum, long pulse, high power backward wave oscillator (BWO). The University of New Mexico long pulse backward wave oscillator, which displays the characteristic “pulse shortening” phenomenon, is investigated in these studies. Although pulse shortening is observed across a wide class of high power microwave (HPM) devices, its origin is not definitively understood. Many hypotheses suggest that the unintentional introduction of plasma into the interaction region near the walls of the SWS is one of several likely causes of pulse shortening in intense beam-driven slow wave devices. We have measured the line-integrated, temporally resolved plasma density between an intense, relativistic, annular electron beam and SWS walls for a variety of radiated microwave peak power levels. Line-integrated electron densities \(<n_e L>\) between \(9 \times 10^{15}\) and \(1.4 \times 10^{16}/\text{cm}^2\) for radiated microwave powers between 20 and 120 MW have been measured. The two main sources of the measured electron density are postulated to be i) plasma generated from the cutoff neck due to beam scrape off, and ii) material removed and ionized from the SWS walls during the course of microwave generation.

Fig. 7. Typical results of (a) the microwave signal and (b) the early phase of the line-integrated plasma density (i.e., phase I plasma).

Fig. 8. Typical line-integrated plasma density signal on a longer time scale.

Fig. 9. Slope of the initial linearly rising part of the line-integrated plasma density, as a function of the microwave pulse duration. The pulse duration is measured at the base at the 10% points of its maximum pulse amplitude.
Students Trained using Instrumentation

The following postgraduate scientists utilized this instrumentation:

1) Dr. Frank Hegeler, Research Assistant Professor
2) Dr. Naz Islam, Research Associate Professor

The following graduate students utilized this instrumentation as part of their research:

1) Chris Grabowski (Ph.D. student, graduate 1998)
2) Gregory Todd Park (M.S. student, to graduate 1999)
3) Robert Wright (Ph.D. student, to graduate 1999)

The following undergraduate students utilized this instrumentation as part of their training as undergraduate research assistants in the Pulsed Power and Plasma Science Laboratory:

1) Tony Peredo (sophomore in the Electrical and Computer Engineering Department)
2) Kelly Hahn (senior in the Electrical and Computer Engineering Department)

Finally, portions of the laser instrumentation, as well as the Educational Retron HPM source will be used as part of EECE 553L, Experimental Plasma Physics and Pulsed Power, a graduate level course to be offered in academic year 1999-2000.
Future Use of Instrumentation

In the next series of experiments, a modified inlet to the slow wave structure in our long pulse backward wave oscillator experiment will be used. This modified inlet is a Bragg Reflector and it is postulated to minimize electron beam “scrape-off,” thereby minimizing unwanted plasma from being introduced into the slow wave structure system. Laser interferometry of this new configuration will be critical in assessing the success of this modification.

An additional experiment is planned whereby the Nd:YAG laser will be utilized to selectively ablate material from specific sections along the slow wave structure during microwave generation. This material ablation will then be correlated with pulse shortening, as well as the laser interferometric measurements.

Presentations and Publications Describing the Utilization of this Instrumentation

The utilization of the instrumentation acquired under this DURIP grant is described in one journal publication, two conference publications, and four conference presentations, as indicated: