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# FLOATING DATA ACQUISITION SYSTEM FOR MICROWAVE CALORIMETER MEASUREMENTS ON MTX[*]

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## Abstract

A microwave calorimeter has been designed for making 140-GHz absorption measurements on the MTX. Measurement of the intensity and spatial distribution of the FEL-generated microwave beam on the inner wall will indicate the absorption characteristics of the plasma when heated with a 140 GHz FEL pulse.

The calorimeter works by monitoring changes of temperature in silicon carbide tiles located on the inner wall of the tokamak. Thermistors are used to measure the temperature of each tile. The tiles are located inside the tokamak about 1 cm outside of the limiter radius at machine potential. The success of this measurement depends on our ability to float the data acquisition system near machine potential and isolate it from the rest of the vault ground system.

Our data acquisition system has 48 channels of thermistor signal conditioning, a multiplexer and digitizer section, a serial data formatter, and a fiber-optic transmitter to send the data out. Additionally, we bring timing signals to the interface through optical fibers to tell it when to begin measurement, while maintaining isolation.

The receiver is an HP 200 Series computer with a serial data interface; the computer provides storage and local display for the shot temperature profile. Additionally, the computer provides temporary storage of the data until it can be passed to a shared resource management system for archiving.

## Introduction

ECRH heating of the MTX experiment requires the launching of microwaves from a 20-kJoule free electron laser into the Alcator C tokamak through a port from the outside of the torus (Fig. 1) Significant refraction of the beam by the plasma is expected in the polodial direction, and the high intensity of the power flux causes a nonlinear absorption of the microwaves by the plasma.[1] Ponderomotive effects become important in addition to the parametric instabilities, which alter the plasma's absorption of the microwave pulse. One method of gaining insight into these processes is by measuring the amount and distribution of microwave energy from the FEL that is transmitted through the plasma.[2]

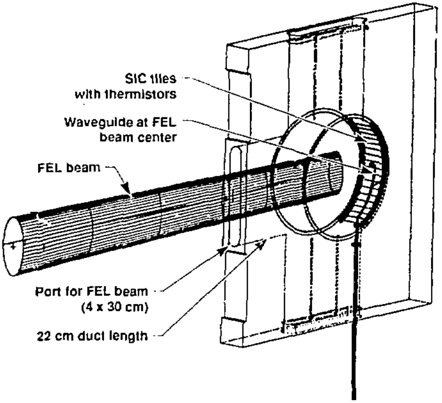

**Figure 1. Location of MTX microwave calorimeter diagnostics.**

## Space Limitations

Inside the tokamak the transmitted microwave energy is distributed across a sizeable arc (Fig. 2) of the poloidal circumference of the torus interior. Alcator C has only 2 cm of space available between the edge of the plasma and the wall when using the 16.5 cm radius poloidal limiters, and the largest slot for access into the primary vacuum vessel is just over 4.2 cm wide.

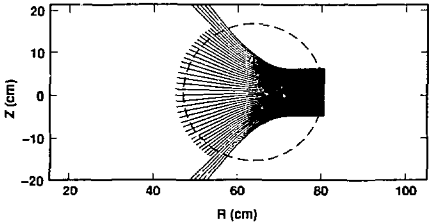

**Figure 2. Trajectory of transmitted microwave energy inside the tokamak.**

## Physical Limitations

Any instrument for use inside the primary vacuum vessel must be constructed entirely out of materials compatible with ultra high vacuum; specifically, the materials must have outgassing rates comparable to that of stainless steel. All materials used in the device must be non-ferromagnetic so as not to significantly perturb the magnetic fields of the tokamak. Additionally, instruments inside of the tokamak are subjected to large heat loads from line radiation, Bremsstrahlung radiation, and neutron damage during a shot. Even behind the main limiters, the edge plasma causes heating and sputtering. Alcator is cleaned daily with Taylor discharges, and during the process the plasma is allowed to expand out to the vessel walls. This process is designed to remove impurities from the machine, but would quickly erode most materials exposed to it.[2]

## Electrical Noise

The plasma radiates across a broad range of frequencies in the gigahertz and megahertz range, and magnetohydrodynamic instabilities radiate in the kilohertz range of the electromagnetic spectrum; additionally, the power supplies for the magnet system create electronic noise at harmonics of 60 Hz The measurement

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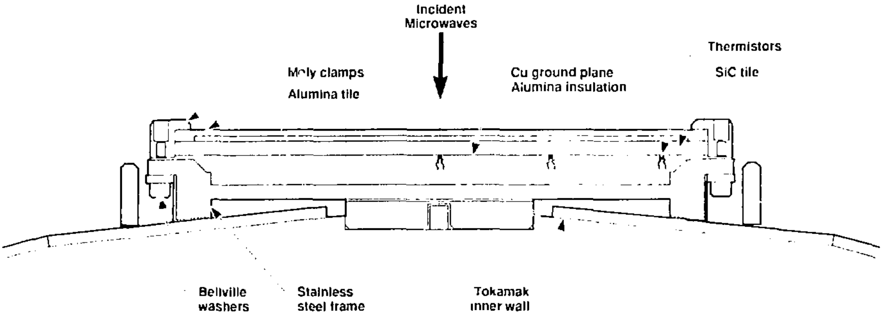

Figure 3a. Arrangement of tiles on the inner wall of tokamak.

of microwave power must therefore be made in a strong dynamic magnetic field

## Methods of Measurement

Two variations on the calorimetric method are often employed to measure microwave power One is to use a bolometer wire in a waveguide Another is to place a thermistor at the end of a waveguide in such a way so that the microwave energy heats *the semiconductor material of the thermistor in* a predictable manner At 140 GHz the dimensions of the waveguide and associated components are so small that they are difficult to construct Even the smallest thermistors available have dimensions of the same order as the free space wavelength of the radiation, making the thermistor absorption of the microwave rather sensitive to local boundary conditions.

A crystal diode detector is another measurement technique, however, diodes are sensitive to the polarization of the radiation, and at 140 GHz the detectors are expensive and it would be extremely difficult to fit a few dozen of them into the space available

Another variation on the calorimetric method is to heat a pad of absorber material with the microwaves, and measure the temperature rise of the system, either with an independent temperature measurement transducer or by allowing the slab to heat a cavity filled with a gas and then measuring the pressure rise in the cavity

## MTX Calorimeter System:

For our application, the absorber material must reflect only a small fraction of the microwave energy, and must absorb it through a small thickness in order *to achieve the highest possible* temperature rise, allowing us to get an accurate measurement from sensors in the noisy tokamak environment. Based on our own measurements of the microwave and vacuum properties of different types of silicon carbide, sintered alpha SiC produced by Standard Oil has been selected for use on the MTX calorimeter.

The calorimeter itself consists of 19 tiles (2 cm × 9 cm × 25 cm) of SiC, shielded with alumina tiles of the same dimension to resist plasma bombardment, and arranged to cover a 108 degree arc on the poloidal circumference of the tokamak The tiles are supported by a frame of stainless steel, which is double hinged to allow it to fit through a 4 2. cm wide slot Figure 3 shows the assembled calorimeter as it will be installed in the C port Fifty-seven thermistors (3 per tile) are attached at various points along the back of the tile mosaic Some of these will be far enough away from the region of peak microwave power deposition to function as reference sensors, measuring the heating of the tiles by radiation from the plasma. The attachment procedure involves vacuum deposition of layers of a copper ground and an alumina insulating layer on the back of the tiles, then gluing the tiny (0.4-mm diam ) thermistors to the back of the tile with a vacuum-compatible ceramic glue. Electrical leads are soldered to the thermistors and brought out of the machine through a bottom port; this completes the sensor portion of the calorimeter system. A heater is used to maintain *the temperature of the tiles thermistor in the appropriate* base temperature.

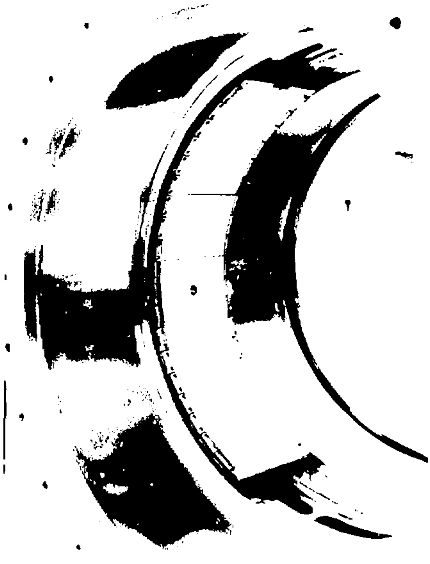

Figure 3b. Cross section of calorimeter arrangement.

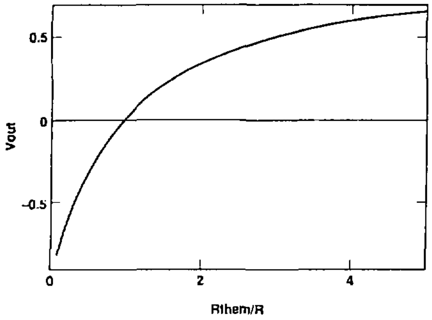

**Figure 4. Thermistor voltage network output as a function of thermistor resistance/fixed matching resistor.**

### Data Acquisition

Since the sensors are at machine potential, we found referencing the entire data acquisition system to the machine was beneficial in terms of electrical noise pickup, and ground isolation. The data acquisition system is battery powered, with individual battery supplies powering each thermistor, and it is connected to the control room via an optical fiber link. The calorimeter data acquisition system has four major parts:

1. Analog signal conditioning
2. Multiplexing and digitizing
3. Sterilizer and data transmission
4. Receiver and analysis

Analog signals originate in a resistive voltage divider, with each thermistor and matching resistor having their own battery power supply to minimize cross talk between channels. Figure 4 shows the output voltage of the divider network as a function of $R_{therm}/R$, where $R_{therm}$ is the resistance of the thermistor, and R is the fixed matching resistor. The first of two signal conditioning amplifiers converts the impedance so as not to load the thermistor voltage divider, and the second one provides a gain of ten to match the dynamic range of the digitizer. We also added a single-pole 50-Hz filter at the second amplifier to attenuate high frequency noise (Fig. 5).

Forty-eight analog signals are routed to the multiplexer, where they are sequentially switched into the digitizer which provides 12 bits of analog-to-digital conversion. The digitizer output register provides gating to separate the high and low order bytes for the serializer. Multiplexer channel numbers are selected sequentially by the word counter, which directs all data flow.

The data frame consists of two eight-bit words of frame synchronization, then 96 words of data (channel 0-47 high and low order bytes), then two eight-bit words of frame end. The serial data was created by a UART chip, and its data capacity is eight bits per serial word, so we broke our data into eight-bit bytes and sent it out in a standard serial format (Fig. 6). Debugging was eased by using standard serial formats, allowing us to simulate

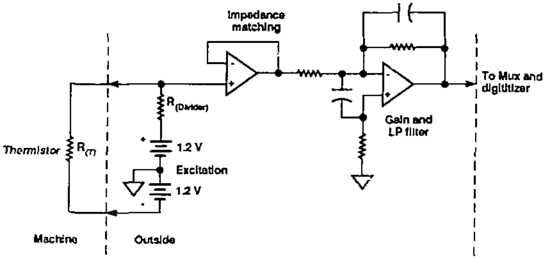

Figure 5. Schematic of battery-powered analog signal conditioning electronics.

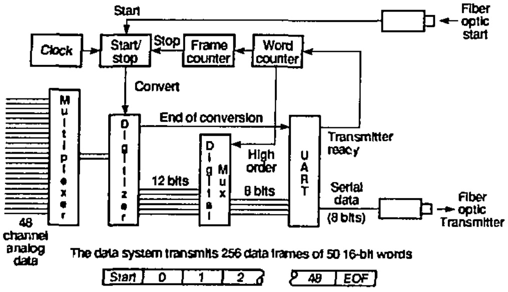

Figure 6. Flow diagram of signal digitizer and multiplexer.

the data in a different computer and transmit it through the data path to our receiver computer.

The data path was optical fiber, allowing 100% ground isolation once the data acquisition system was battery powered and referenced to the machine

To receive the data we used an HP 200 series computer with a data link interface at 28.8K baud; this allowed us a faster bit rate than 19.2K bits per second (serialization of each data channel is the speed bottleneck). Currently, we can digitize each channel at a 25 Hz sampling rate, which should be fast enough. However, we have an option to double the serial data rate and the sample rate as well if necessary. Additionally, the HP computer unpacks the data and produces a preliminary plot between tokamak shots; it then sends the data to a VAX computer system for archiving.

## Conclusion

At this writing, we have successfully completed preliminary tests on a prototype calorimeter. We have constructed, benchtested, and installed the final version of the calorimeter and data system, and have transmitted plasma-generated data through the data receiver to the analysis routine. We are currently awaiting consistent FEL pulses, coupled with tokamak plasmas.

## Acknowledgments

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