RF POWER MEASUREMENTS ON THE DIII-D GYROTRON INSTALLATION

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Introduction

- The ECH injection power is not measured on each shot in many other facilities. Our goal is the development of a reliable power measurement system which can be used for every plasma shot in DIII-D.
- There are two approaches,

Method	Measure the gyrotron power and calculate the transmission efficiency	Measure the power just before ECH Launcher
Problem	•Cooling water temperature fluctuation •Uncertainty of transmission efficiency	•Requirement to be insensitive to polarization •Calorimetric method is not available

Gyrotron Power Measurement

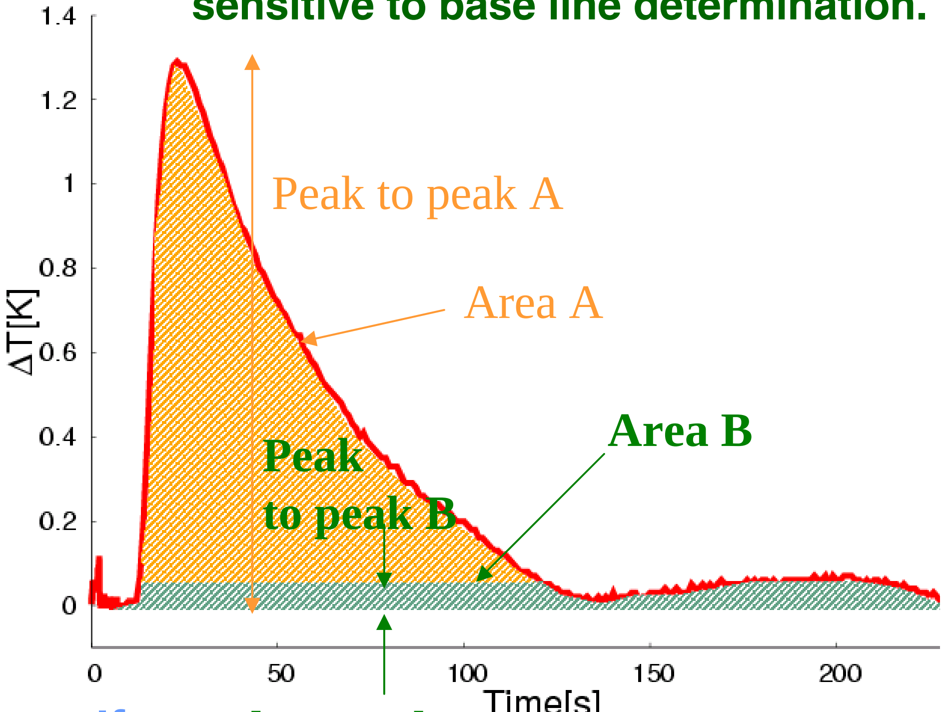
Gyrotron power is estimated by a calorimetoric measurement of heating of components which have a known loss of gyrotron rf power.

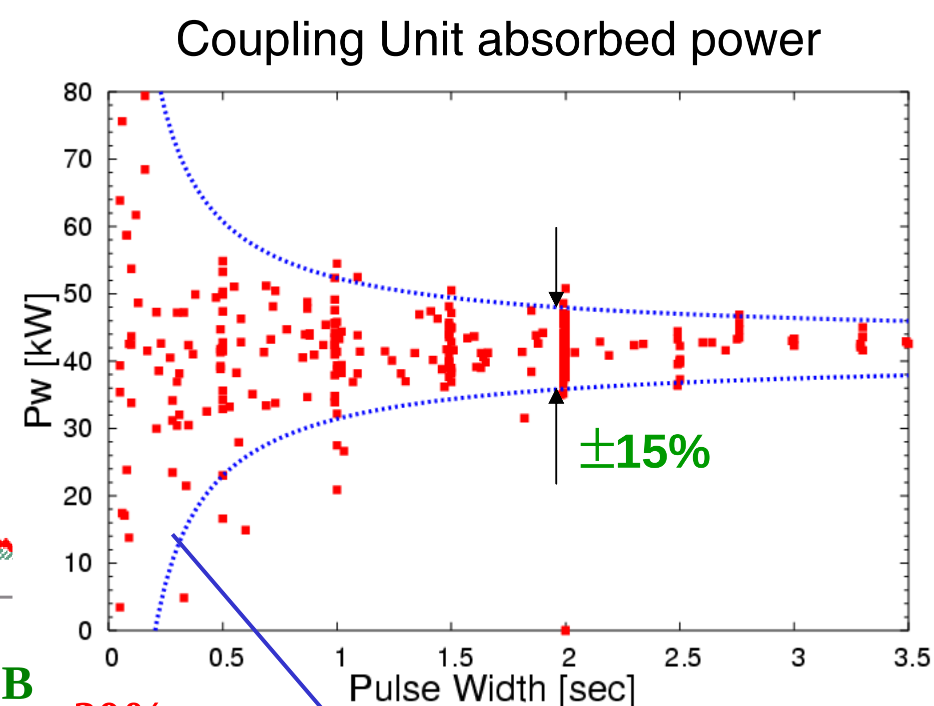
Known rf losses in DIII-D system

Components	Loss rate	Loss Power
Diamond Window	0.02%	2kW
Cavity	2%	20kW
Coupling Unit	5%	60kW
Miter Bend	1%	10kW

Effect of Temperature Fluctuation of Cooling Water

- The gyrotron power is estimated by a calorimetoric measurement of heating of components which have a known loss of gyrotron rf power.
- The calorimetric power measurements have a difficulty. The obtained power is sensitive to base line determination.





If $\frac{\text{Peak to peak B}}{\text{Peak to peak A}} = 10\%$, then $\frac{\text{Area B}}{\text{Area A}} \sim 30\%$

Possible measurement error by typical water temperature fluctuation 0.04K.

It means the ±5% ΔT fluctuation can make ±15% error of power measurement

Note: Signal is small, for example, window temperature increase is less than 1 degree with 2 sec ECH pulse.

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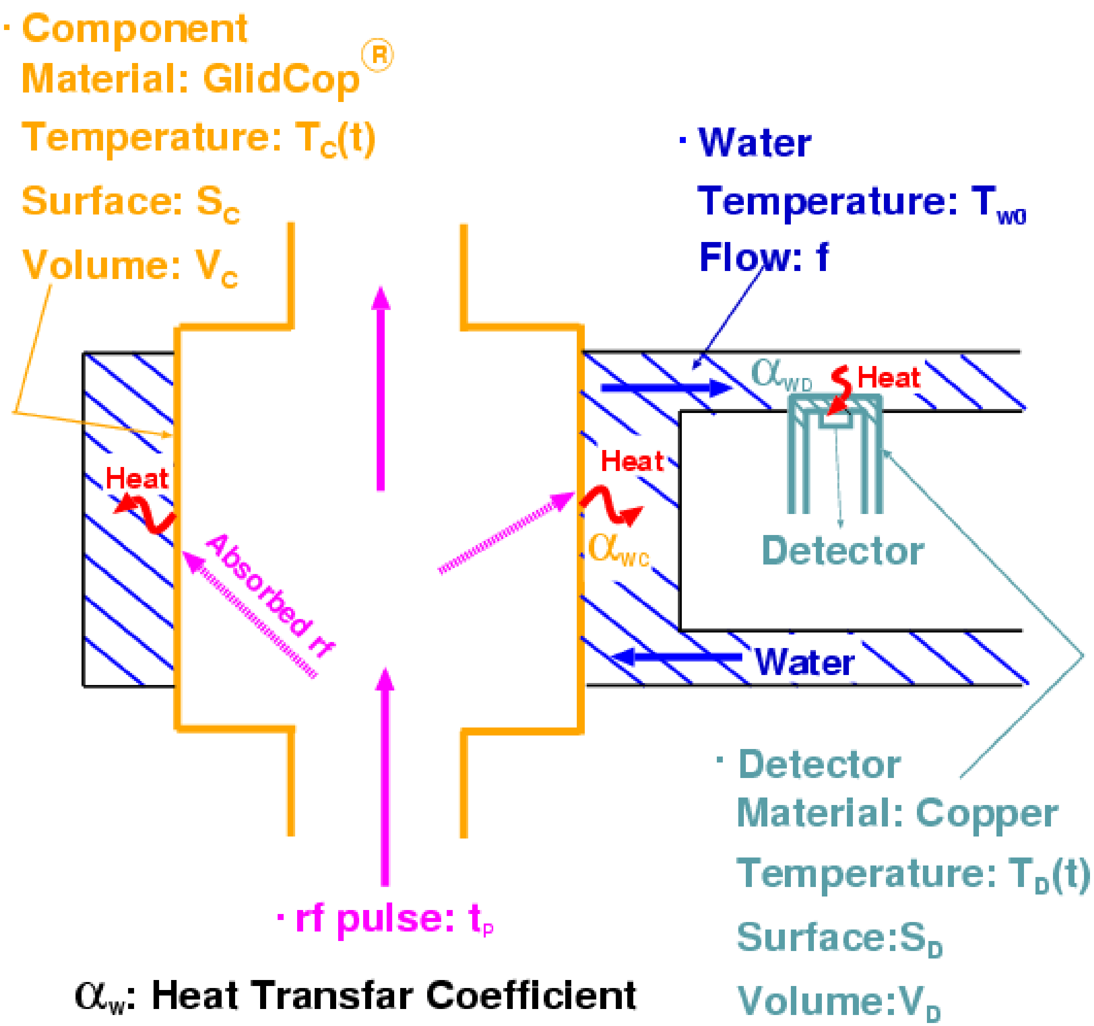
Water Cooling Model for Fitting Function

In order reduce the effect of fluctuating water temperature, a fitting function for calorimaetry signal is developed.



- **Zero-dimensional model**
- **No heat diffusion during the transition from a component to the detector**

Simultaneous Differential Equation

During pulse

$t < t_p$

Component

$$\frac{dT_{C1}(t)}{dt} = -\frac{\alpha_{wC} S_C}{C_C}\left(T_{C1}(t) - T_{w0}\right) + \frac{1}{C_C} P_W$$

Output

Input from rf

Detector

$$\frac{dT_{D1}(t)}{dt} = \frac{\alpha_{wD} S_D}{C_D}\left(\frac{\alpha_{wC} S_C}{C_C}\left(T_{C1}(t) - T_{w0}\right) + T_{w0} - T_{D1}(t)\right)$$

Input

Boundary Condition

$$T_{D1}(0) = T_{w0}, \quad T_{C1}(0) = T_{w0}.$$

After pulse

$t > t_p$

Component

$$\frac{dT_{C2}(t)}{dt} = -\frac{\alpha_{wC} S_C}{C_c}\left(T_{C2}(t) - T_{w0}\right)$$

Output

Detector

$$\frac{dT_{D2}(t)}{dt} = \frac{\alpha_{wD} S_D}{C_D}\left(\frac{\alpha_{wC} S_C}{C_w}\left(T_{C2}(t) - T_{w0}\right) + T_{w0} - T_{D2}(t)\right)$$

Input

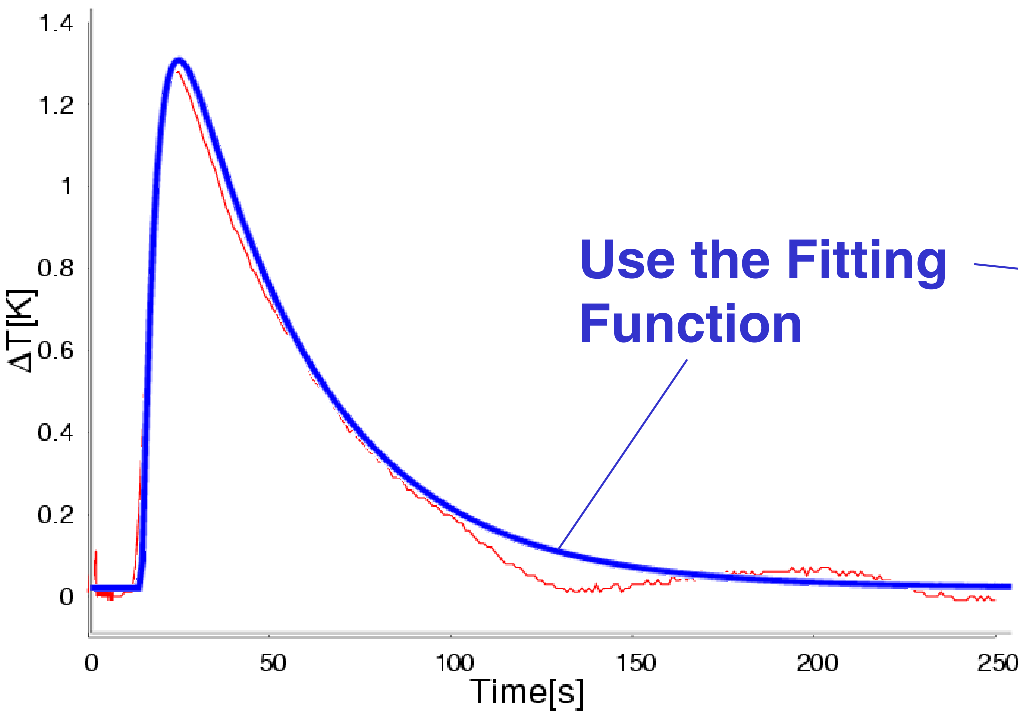
Boundary Condition

$$T_{D2}(t_p) = T_{D1}(t_p), \quad T_{C2}(t_p) = T_{C1}(t_p).$$

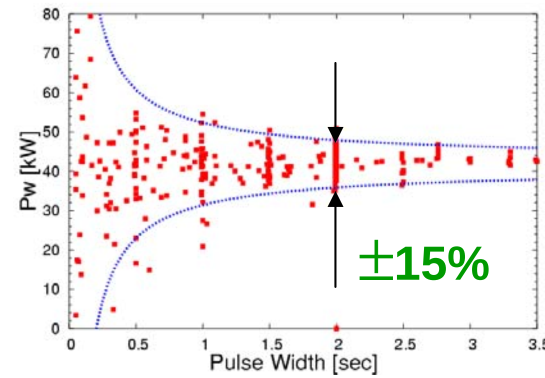
P_W: Absorbed Power
t_p: Gyrotron Pulse Width
T_C : Temperature at component
T_D : Temperature at Detector
T_{w0} : Input water temperature

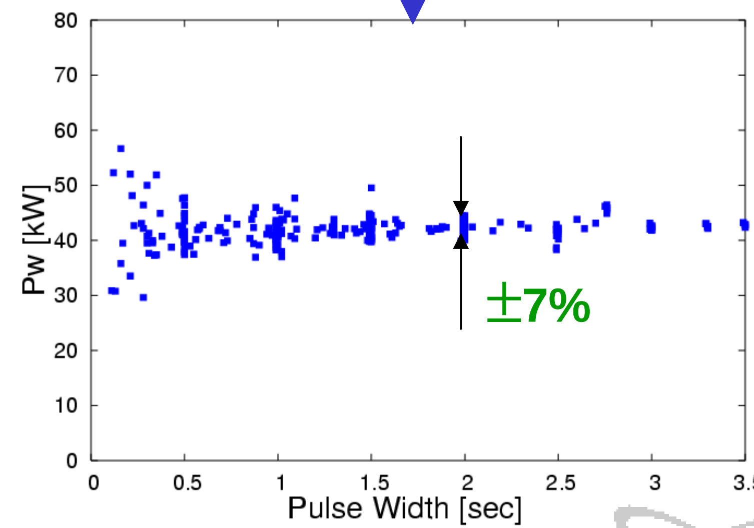
Effect of Temperature Fluctuation of Cooling Water

- By using the fitting function, the scatter in the measurements is reduced from +-15% to +-7% with 2 sec pulse.
- The fitting function is especially useful for short pulse such as 0.5 sec shot.



Use the Fitting Function





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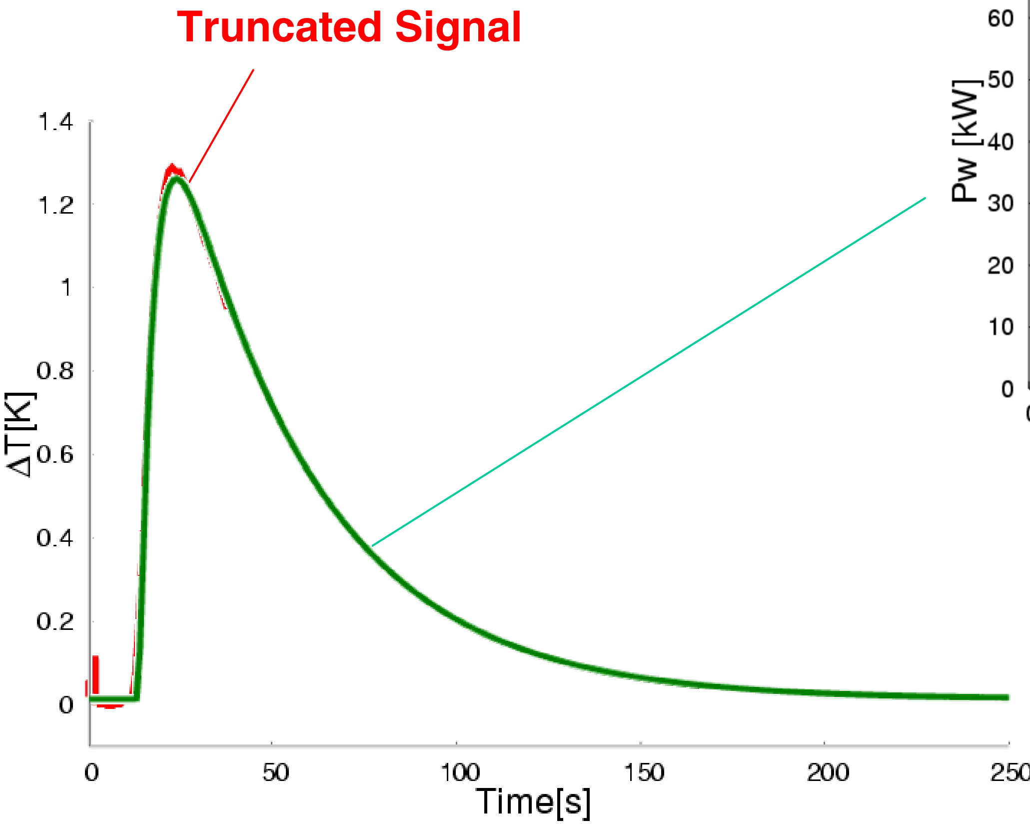
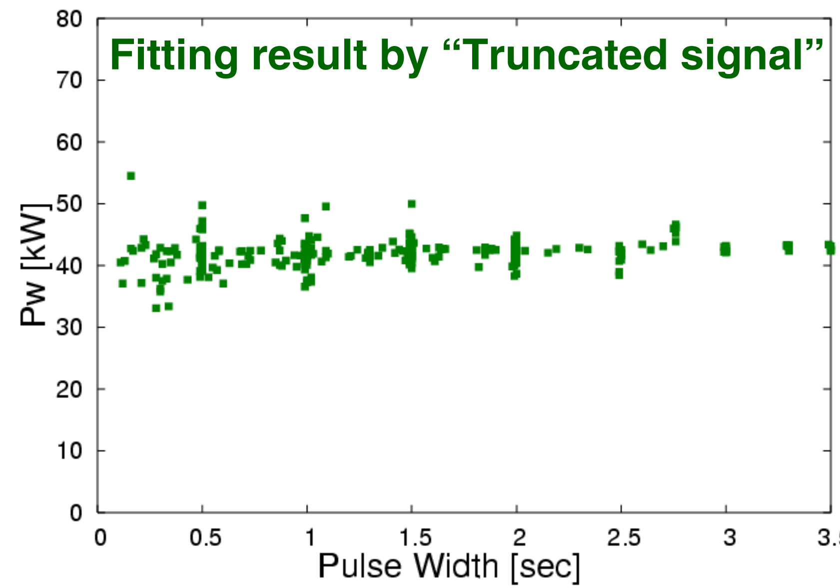
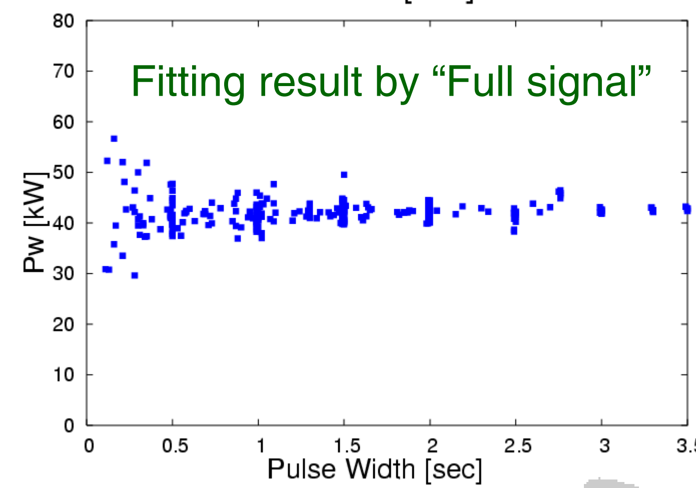
Fitting to Truncated Calorimetry Signal

- **The fitting function is working for "truncated signal" also.**







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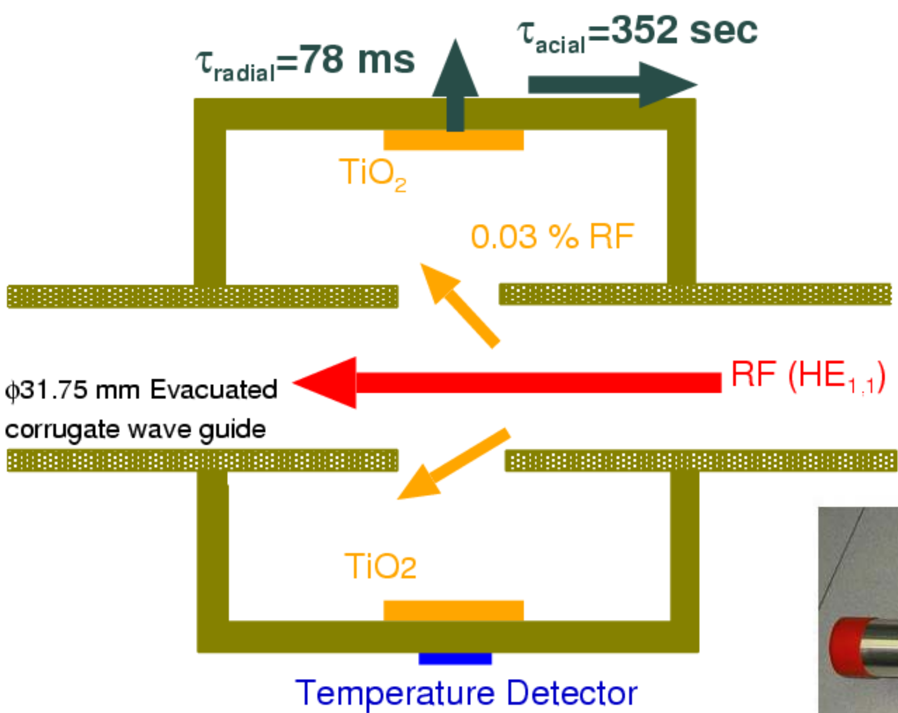
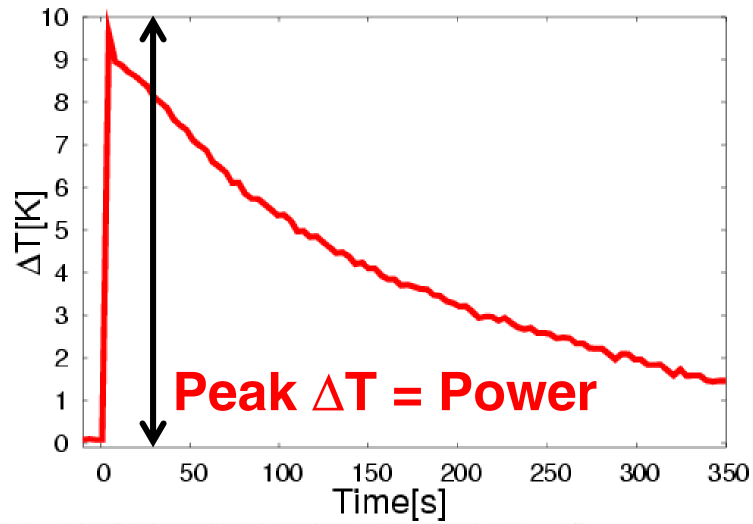
Wave Guide Power Monitor

- A new conceptl built-in wave guide power are developed by J.L.Doane in General Atomics.
- Operation of the power monitor depends on the rapid heat conduction through the wall of the cylinder at the location of the TiO_2 compared with the longitudinal thermal conduction. The response is linear and the peak value of the temperature vs. time can be used to determine the power. S/N ratio is good.





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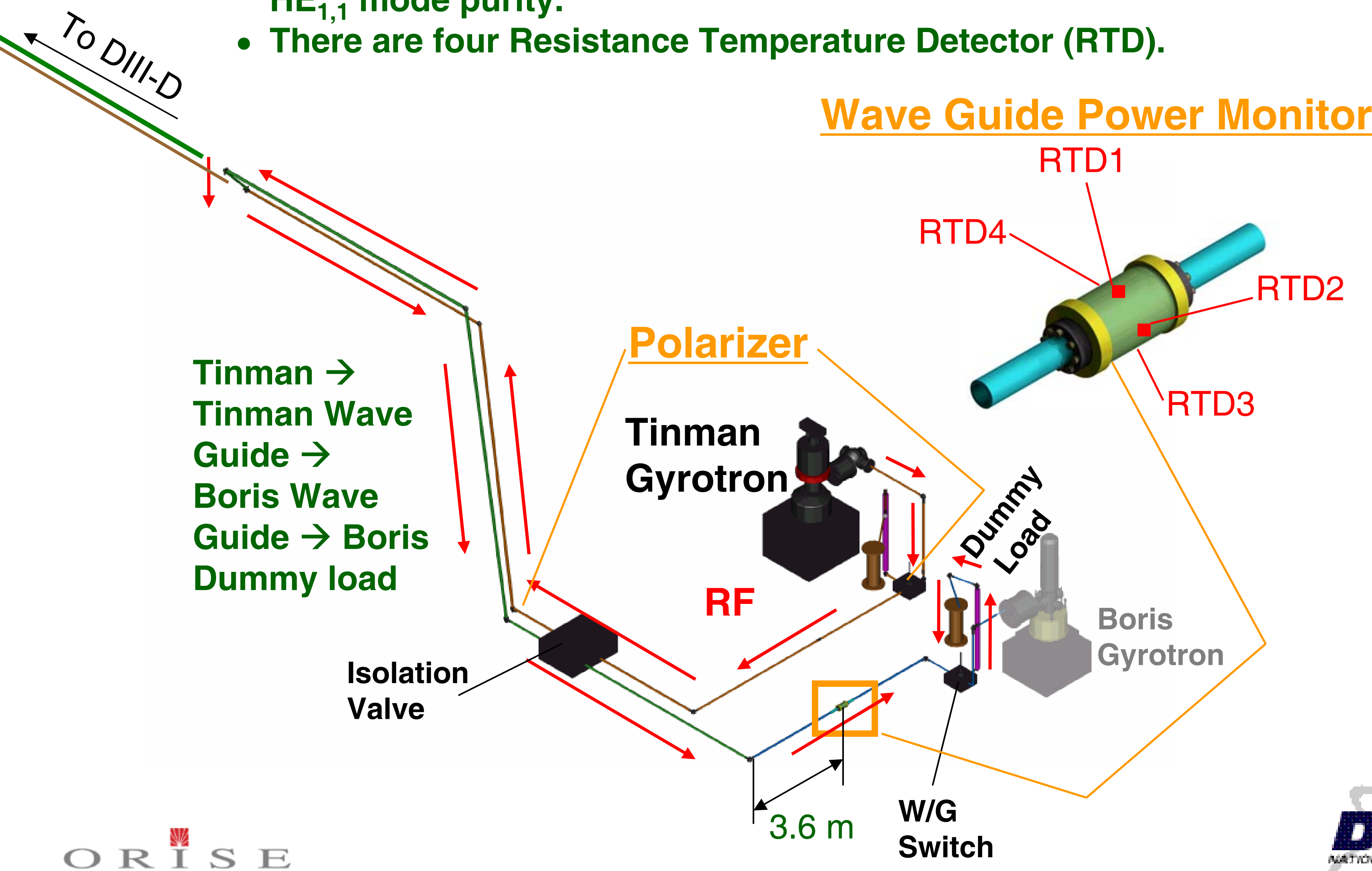
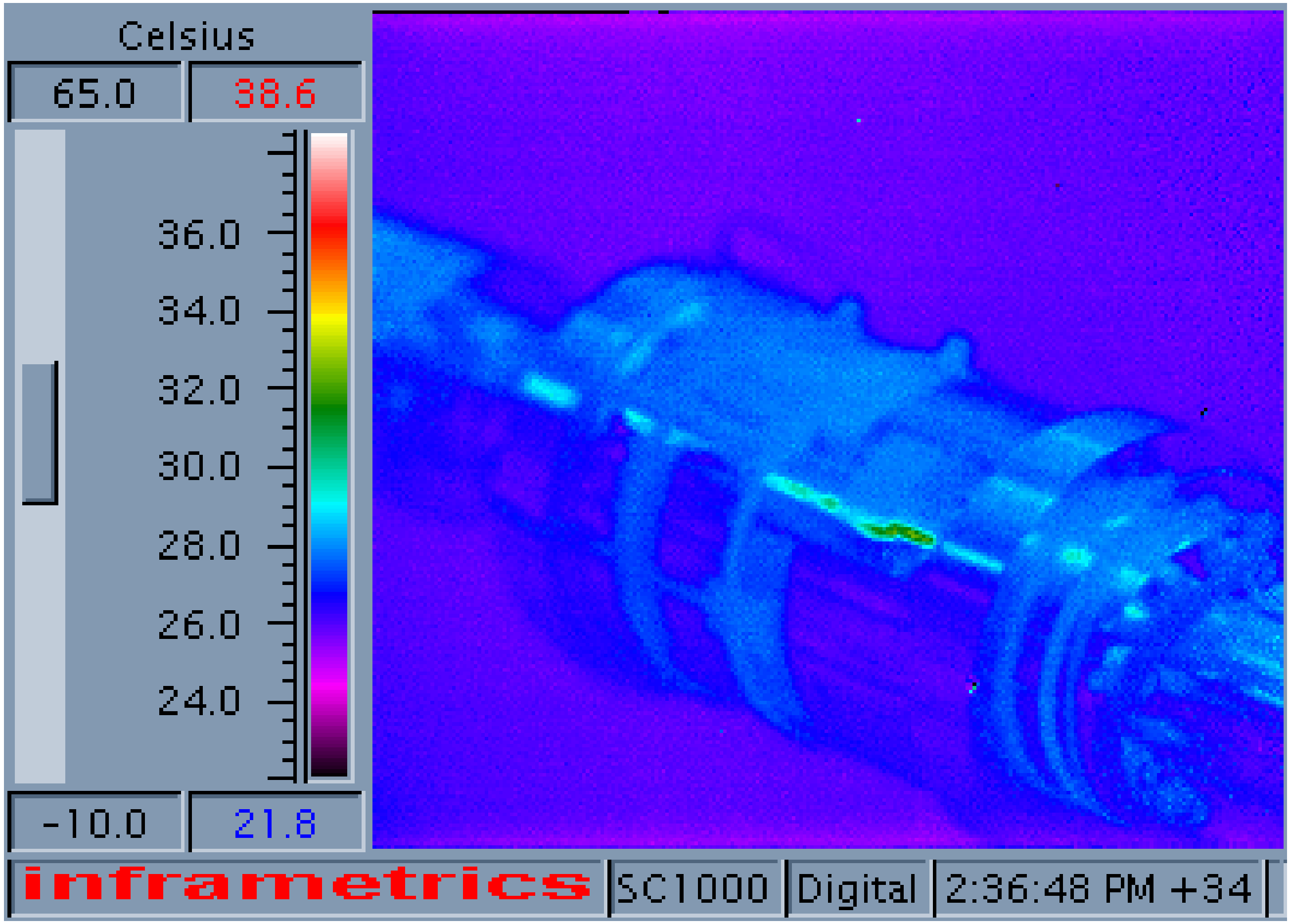
Calibration Setup

- A calibration is attempted by using the long wave guide system which is comparable to the real wave guide length of ~90m in order to increase $HE_{1,1}$ mode purity.
- There are four Resistance Temperature Detector (RTD).



Temperature Increase of Power monitor

- The power monitor is very sensitive to non-$HE_{1,1}$ modes.
- Non-uniform temperature profile is found.



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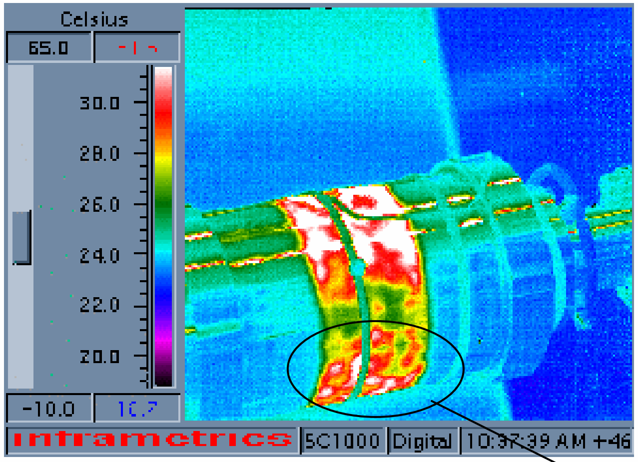
Polarizer Dependence

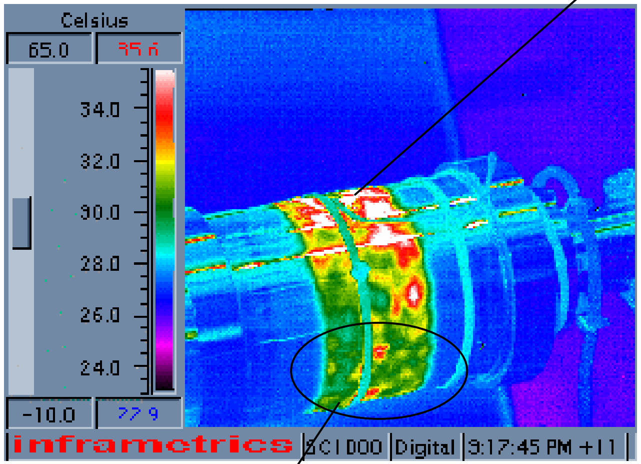
- Polarization sensitivity was found due to small mode conversion at nearby miter bends in the test setup.

Polarizer 0

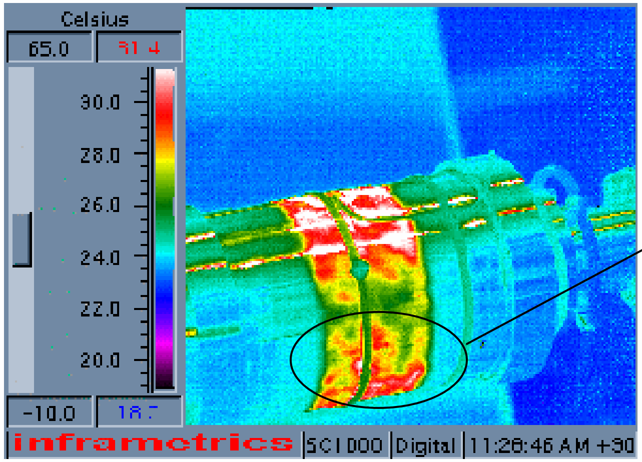


Reflection?

Polarizer 40



Polarizer 20



Clear Difference

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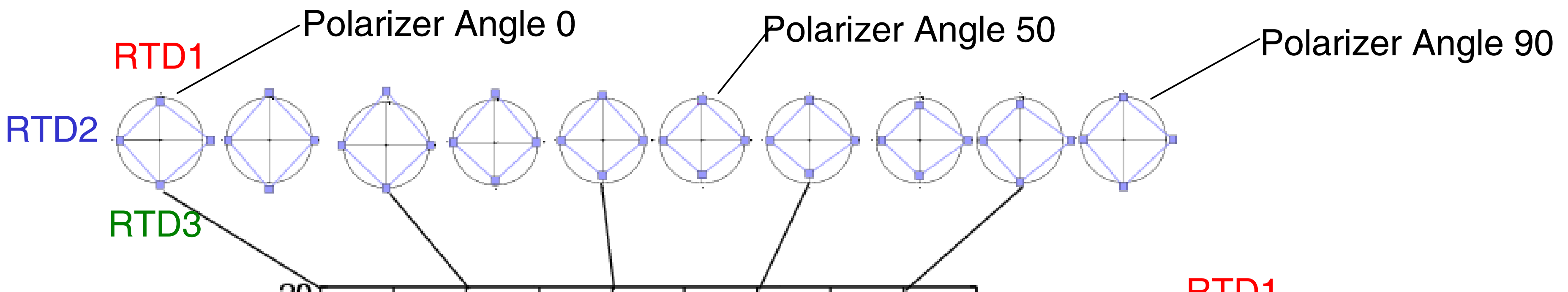
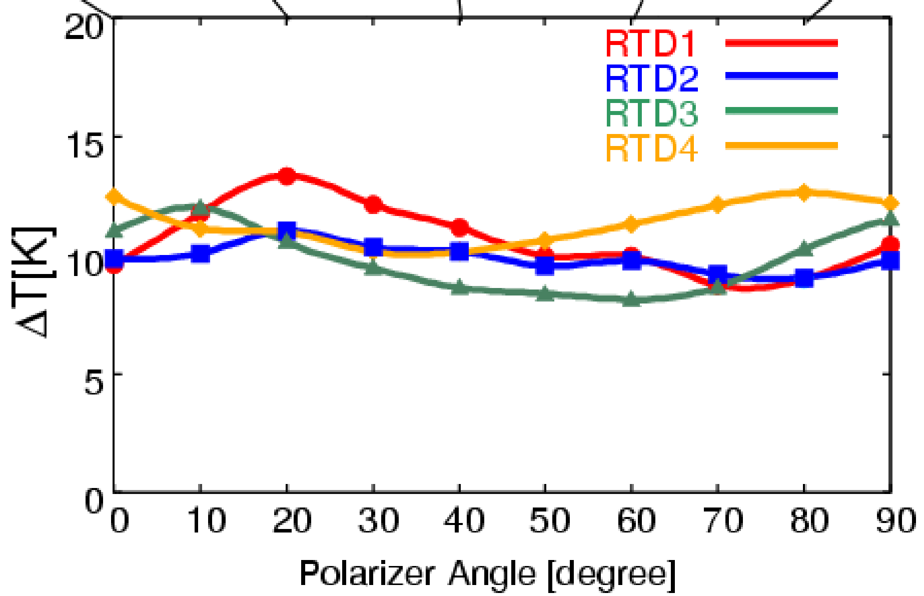
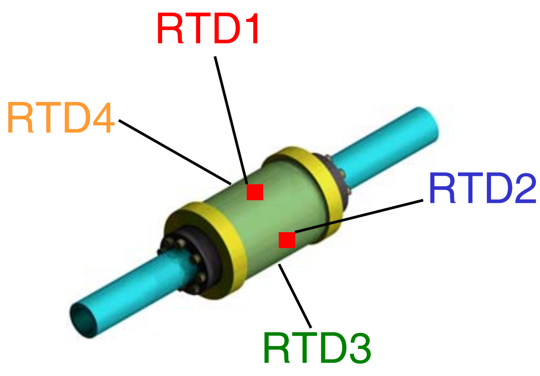
Random Change by Polarizer Setting

- **The "temperature profile" is NOT rotating as polarizer rotates.**







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Summary

1. Fitting function for calorimetry signal has been developed in order to avoid the effect of water temperature fluctuation on gyrotron power measurement
   1. The accuracy of the rf absorbed power measurement is improved from +-15% to +-7% (case of coupling unit)
   2. Fitting function has a good capability for “truncated signal”, giving improved response time
2. A new concept built-in wave guide power monitor has been tested using a long wave guide system (comparable to real experimental set up)
   1. Non-uniform azimuthal temperature increase is observed
   2. A strong polarization dependence is found.
   3. The non-uniform temperature space profile does not rotate as the wave polarization rotates.

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