Laser heating investigation of SRF Nb cavities

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6th SRF Materials Workshop

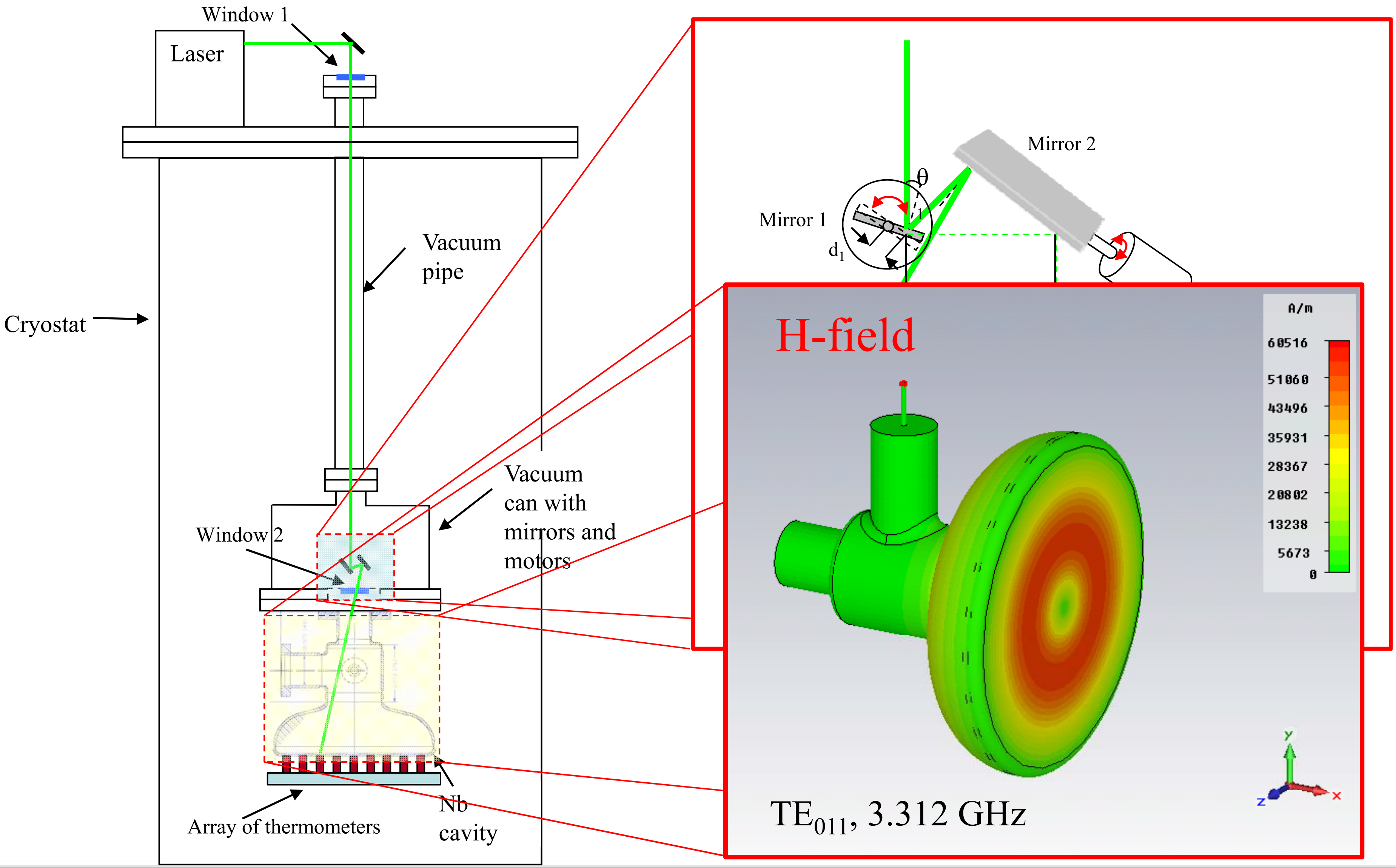
National High Magnetic Field Laboratory, 18-20 February, 2010

Objective

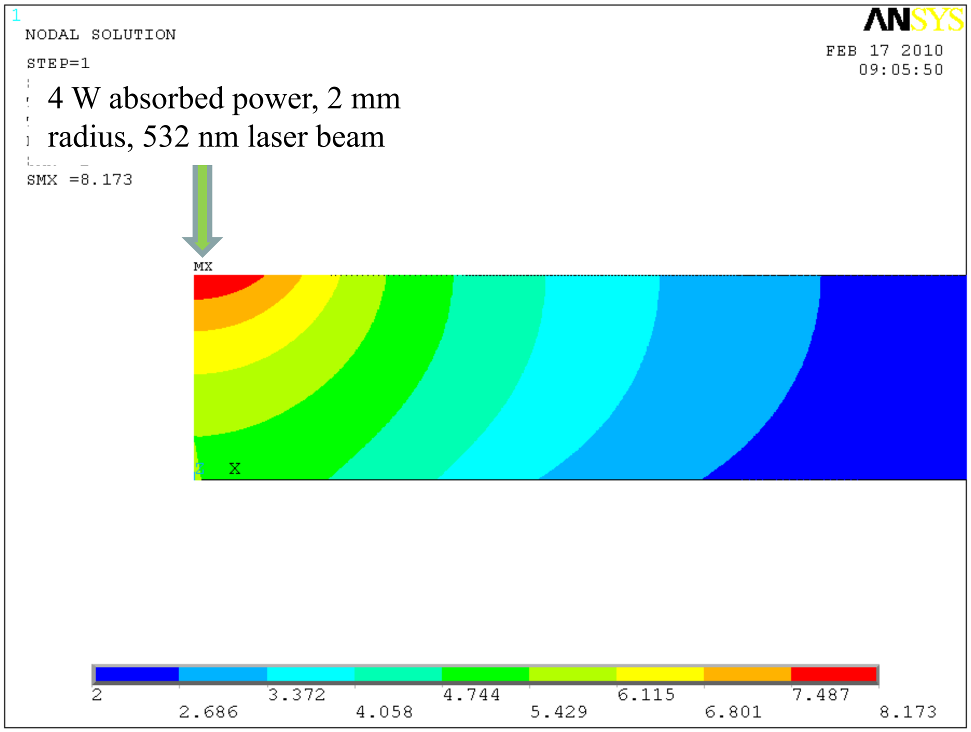
- Explore the influence of pinned vortices in generating anomalous RF losses, particularly at high-field (Q-drop region)
  - Depin vortices by applying a local thermal gradient using a laser beam directed to regions of the cavity surface which show high RF losses

- Explore Laser Scanning Microscopy as a non-destructive technique to identify lossy regions of a cavity with better spatial resolution than by thermometry.

Method


Window 1
Laser
Vacuum pipe
Cryostat
Window 2
Vacuum can with mirrors and motors
Array of thermometers
Nb cavity
Mirror 2
Mirror 1
θ
d_1
H-field
A/m
60516
51060
43496
35931
28367
20802
13238
5673
0
y
z
x
TE_{011}, 3.312 GHz

Thermal analysis



- Theoretical estimate of thermal gradient necessary to overcome the pinning force in Nb at 2K:

$$\left|\nabla T\right|_c \cong \frac{J_c \mu_0 T_c^2}{2 B_{c1} T} = 1.5\,\mathrm{K/mm}$$

- Thermal gradient at the inner surface due to 4 W absorbed power, 4 mm diameter green laser beam: ~ 2.3 K/mm

Laser Scanning Microscopy

- Perturb the surface of the cavity end-plate with a modulated laser spot to cause local heating
- Measure the change in f_0 and Q_0 as the laser spot is scanned over the surface ⟹ calculate the local RF current density

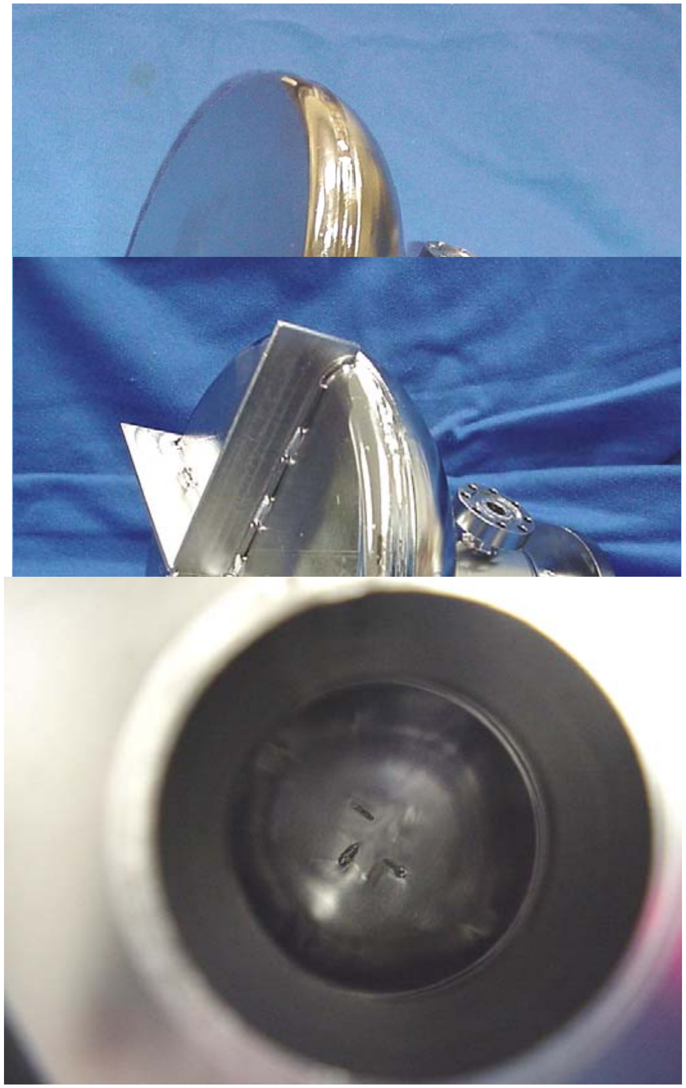
- For LSM of an SRF cavity, the volume perturbed by the laser, compared to stored energy, limits the spatial resolution.

The estimated change in f_0 due to 4 W absorbed power from a green laser beam 4 mm diameter is

$$\frac{\delta f}{f_0} = -\frac{\delta U_M}{U} \cong -C_{cav}^2 \frac{A\delta\lambda}{2\mu_0} = -6.88 \cdot 10^{-10}$$

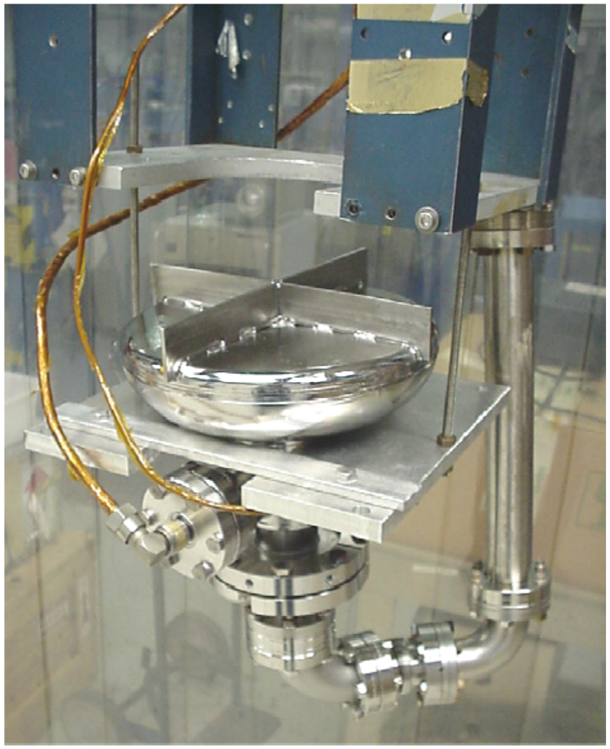
where C_{cav} = 75.8 mT/√J is a geometry constant for the TE_{011} mode

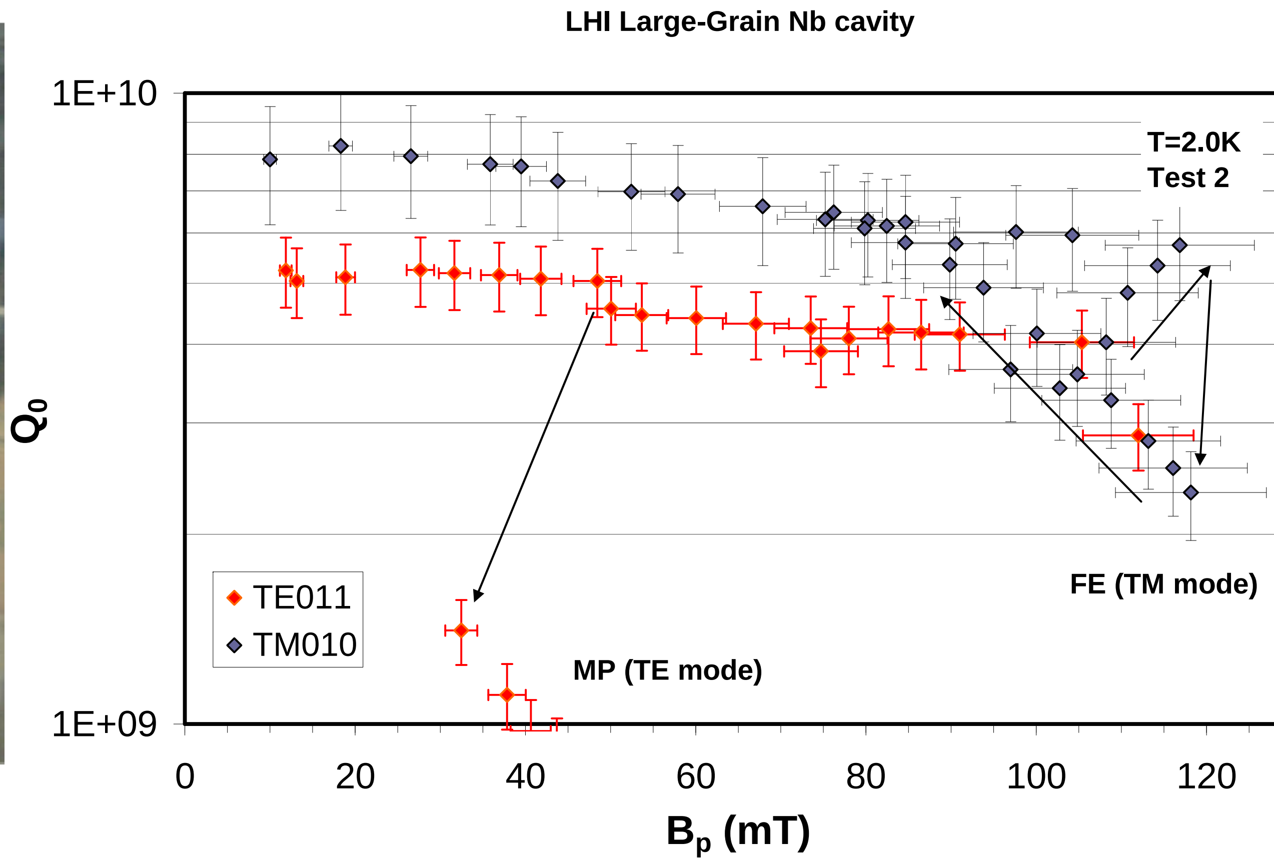
Nb cavity fabrication



- The cell shape is the same as the one for the DESY “gun” cavity
- The cell was built from CBMM large-grain Nb
- 2 holes during the equator EBW had to be repaired
- The center of the flat-plate (heat treated at 800 °C) caved in ~0.25” after evacuating the cavity at room temperature
- 4 stiffening ribs had to be welded on the flat plate. 4 large pits are visible on the inner surface near the center of the plate, after welding

Cavity RF test results





- We'll try:
  - He processing
  - Operate in a different mode, for example TM_{020} at 2.66 GHz
  - Analyze MP trajectories with a 3D code

Conclusions

Experiments where a high-power laser beam is scanned on the inner surface of an SRF cavity are being planned in order to study the influence of pinned vortices on the Q-drop and the possibility of measuring the local RF current density by laser scanning microscopy

- A half-cell with flat end-plate operating in the TE_{011} mode has been built out of large-grain Nb
- The laser scanning and thermometry systems have been designed and are currently being built
- The main obstacle so far is a very strong multipacting barrier found at about B_p=45 mT, limiting the cavity RF performance at 2 K

Acknowledgements

- **JLab**: G. Cheng, B. Clemens, P. Kneisel, K. Jordan, G. Slack, L. Turlington, H. Wang

- **FSU/NHMFL**: A. Gurevich

- **U. of Maryland**: S. Anlage

- **BARC**: J. Mondal