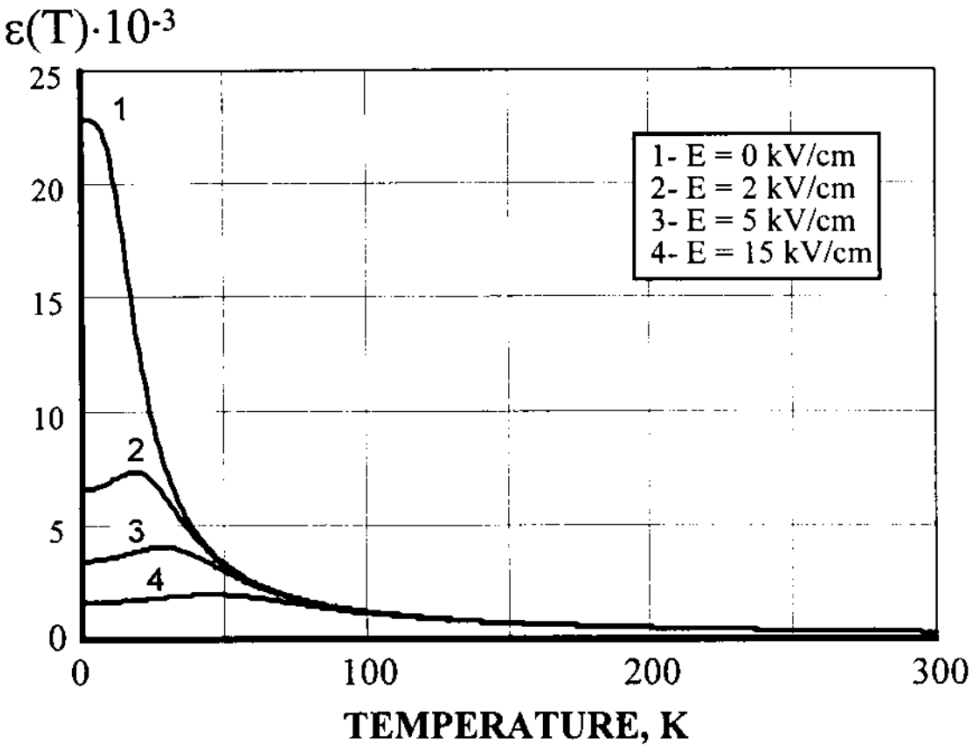
Cavity tuning with dielectrics

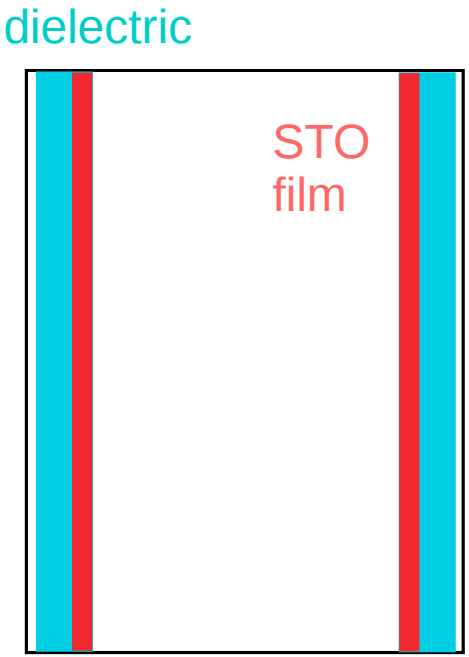
Daniel Bowring, Srinivasulu Gollapudi, Shashank Priya, Chiara Salemi, Andrew Sonnenschein, Alvin Tollestrup

2nd Workshop on Microwave Cavities and Detectors for Axion Research

13 January 2017

Motivation



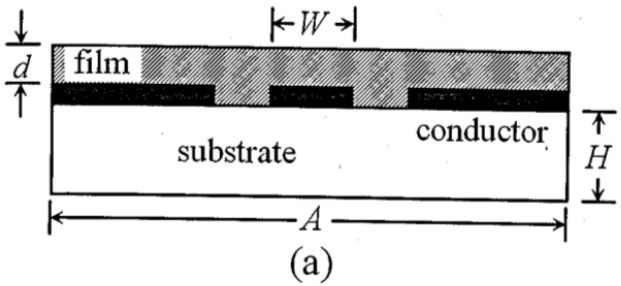


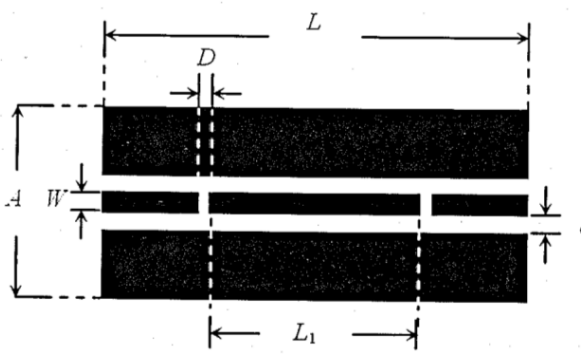
- O.G. Vendik *et al.*, J. Supercond. **12,** 2 pp. 325-338 (1999).
- Nonlinear dielectric films (e.g. strontium titanate, STO) change permittivity with DC bias, temperature.
- This can potentially be used for **fine tuning** of cavities.

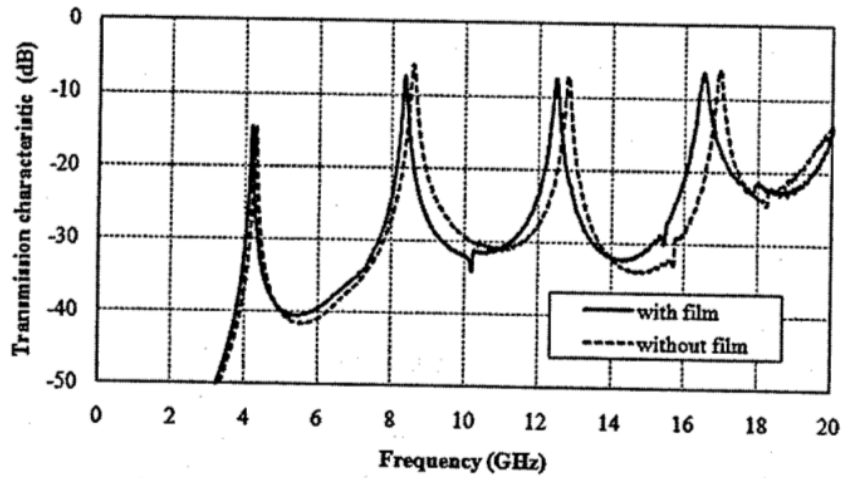
Outline of experimental program

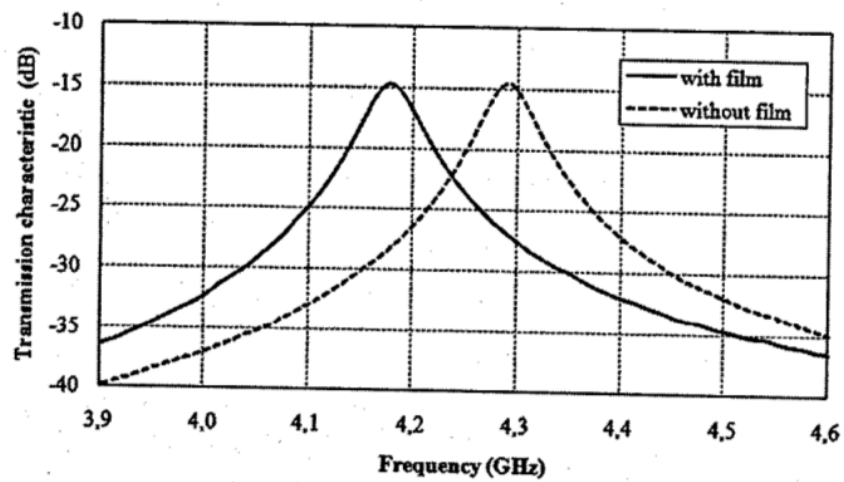
(1) Design & build coplanar waveguide resonator
(2) Generate STO samples
(3) Cryogenic resonator characterization
(4) Tuning demonstration
(5) 3D resonator demonstration

Coplanar waveguide resonator



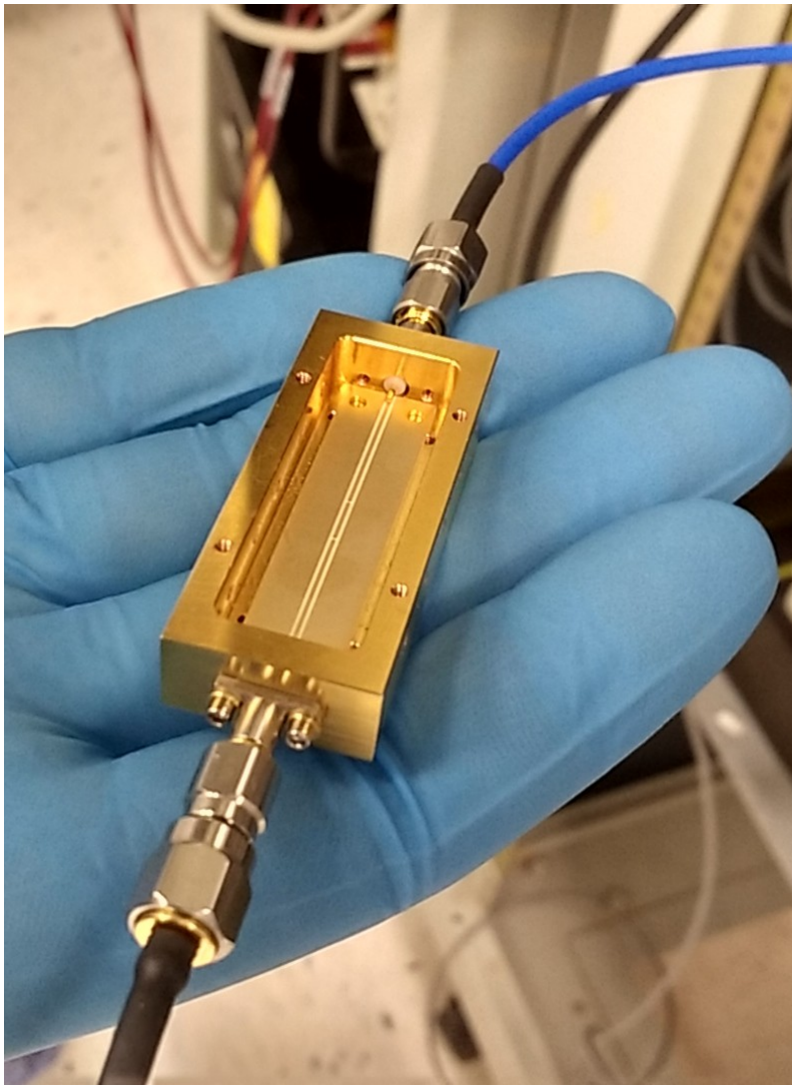


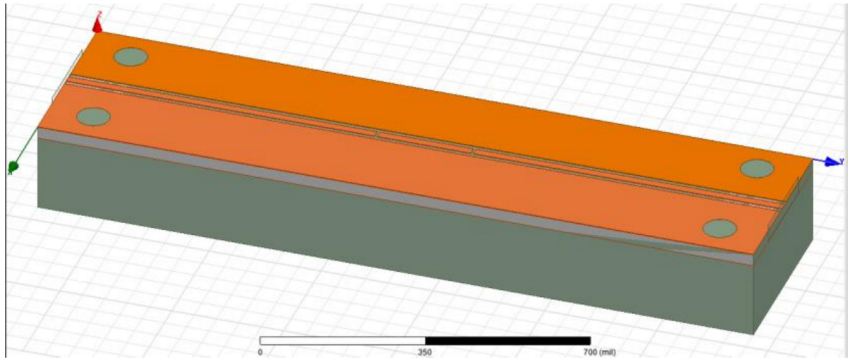


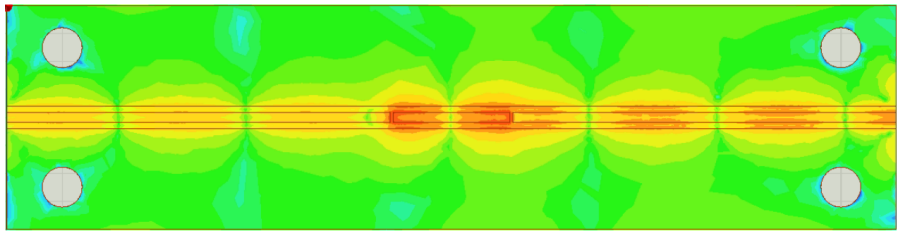


J.I. Marulanda *et al.*, Micro. Opt. Technol. Lett. **53**, 10 pp. 2418-2421 (2011).

Coplanar waveguie resonator

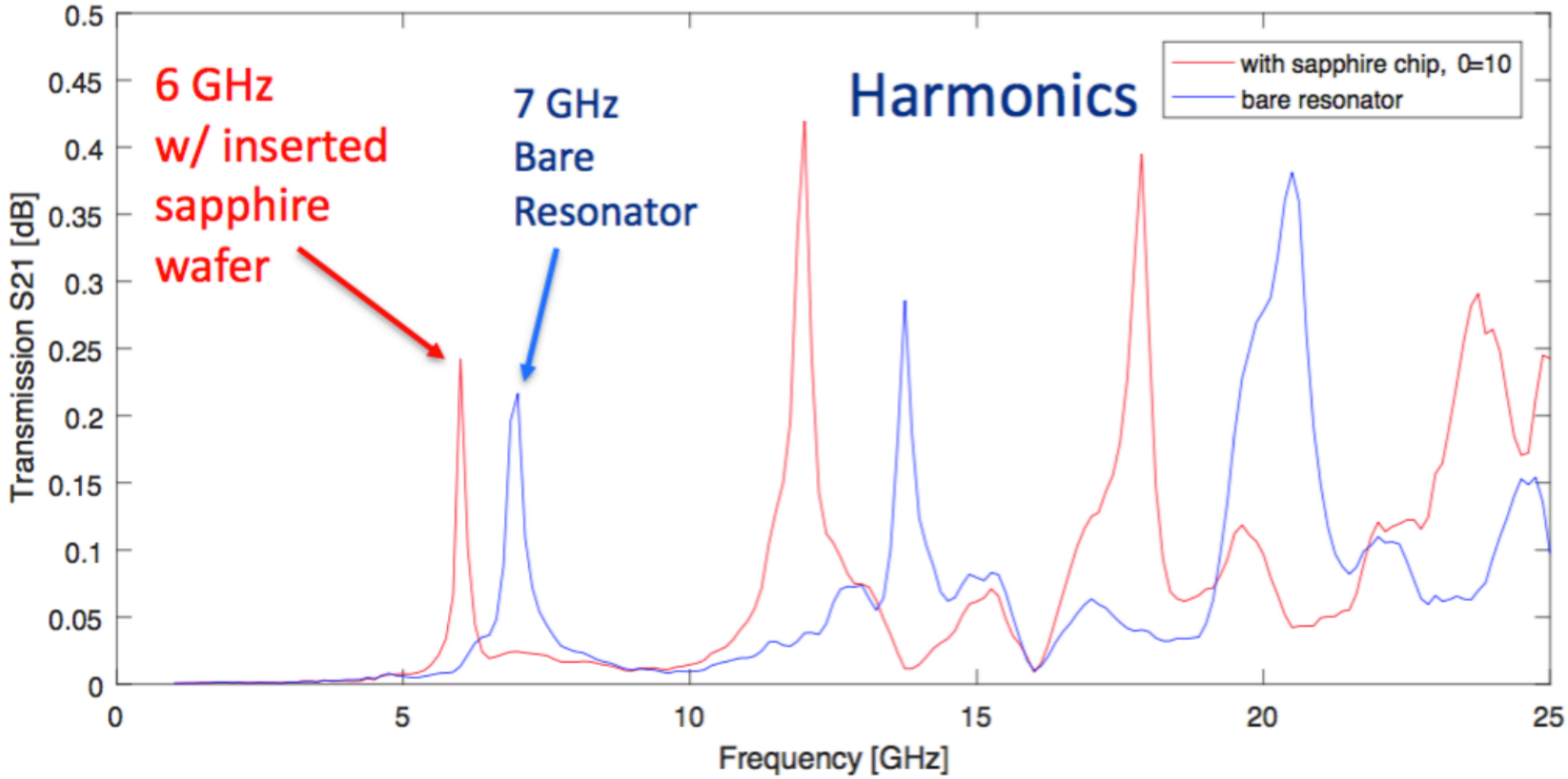






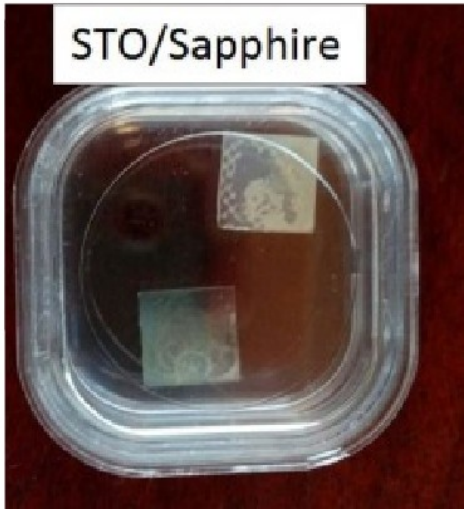
- 3 mil Cu/Au traces
- Rogers TMM10i dielectric
- ~7 GHz fundamental mode

CPWG spectrum



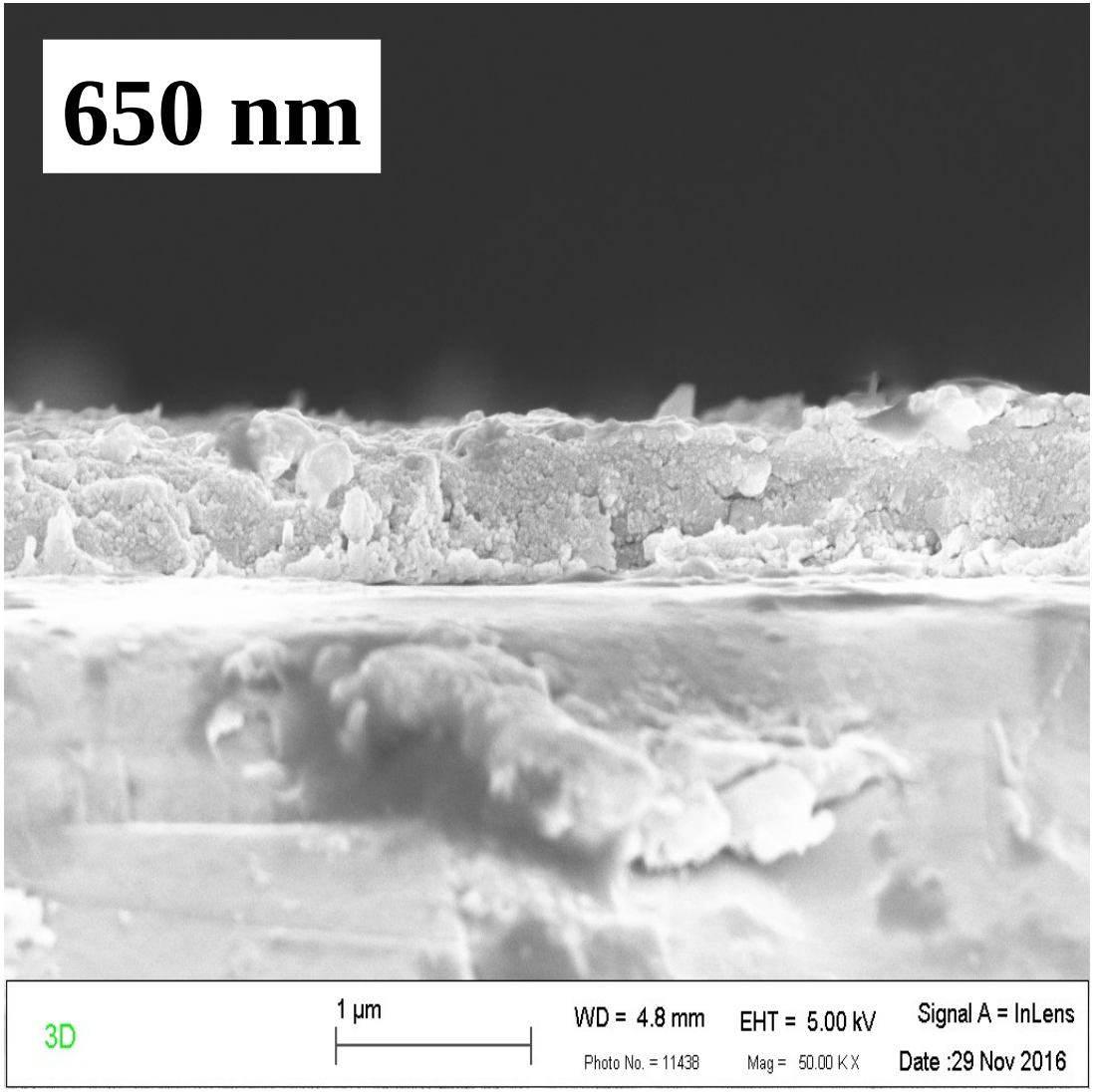
Fermilab

Nonlinear dielectric films



- STO samples provided by S. Priya, S. Gollapudi at VA Tech.
- Aerosol deposition, ~650 nm STO directly on quartz
- Better quality/uniformity than previous films sputtered on sapphire.

After Annealing (S. Gollapudi)



Annealing condition:

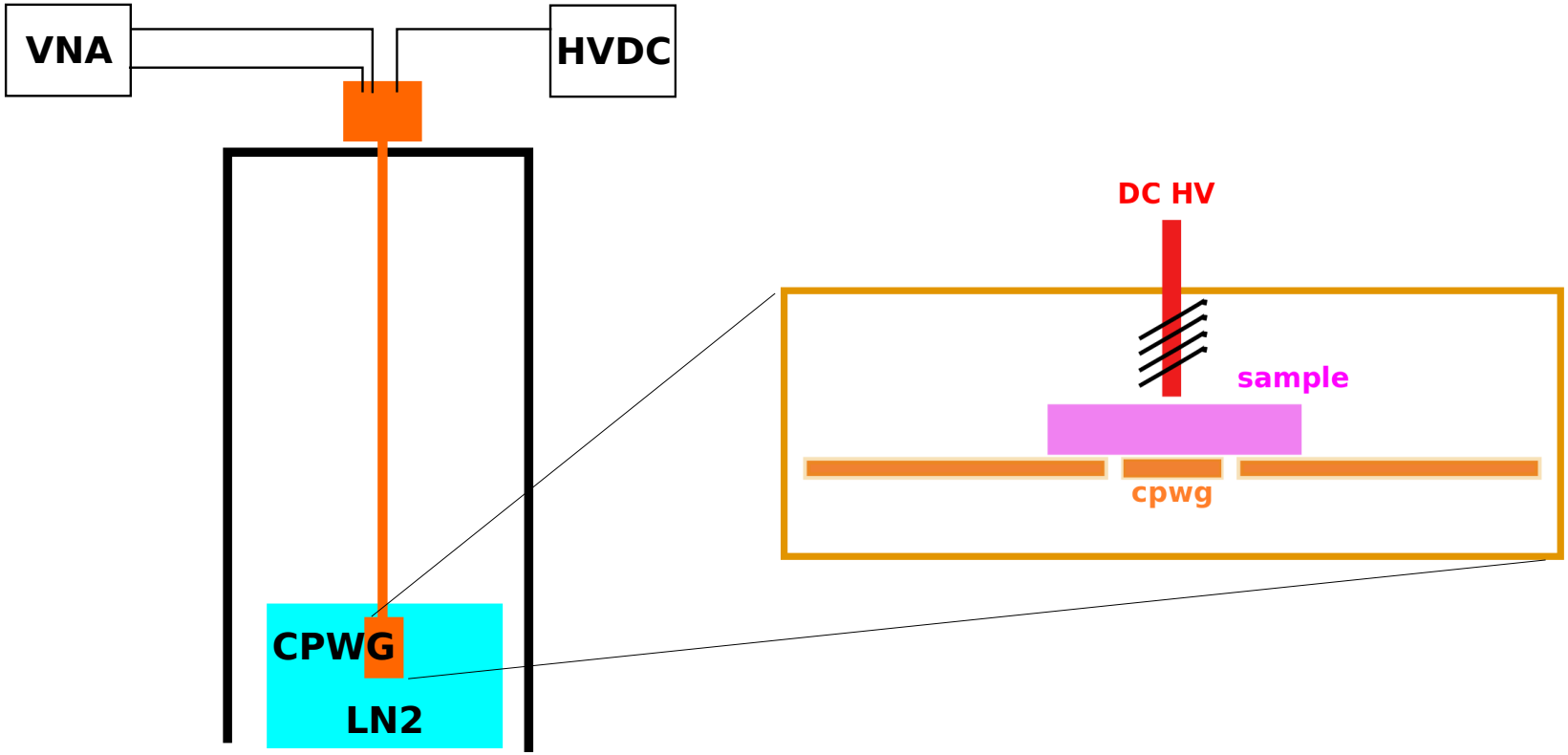
Annealed at 750°C/ 1h

Heating rate 1°C/min

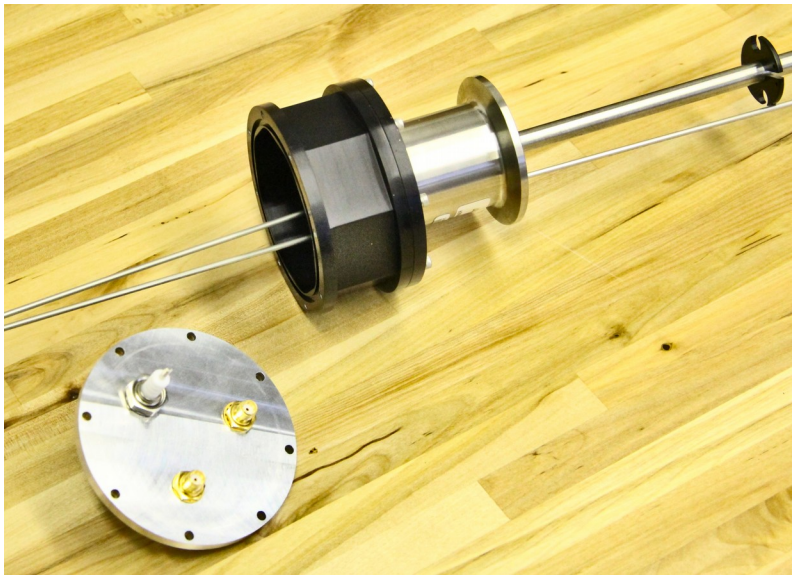
Cooling rate 0.5°C/min

Shrinkage after annealing, ~ 13%

Measurement setup (FNAL SiDet axion lab)

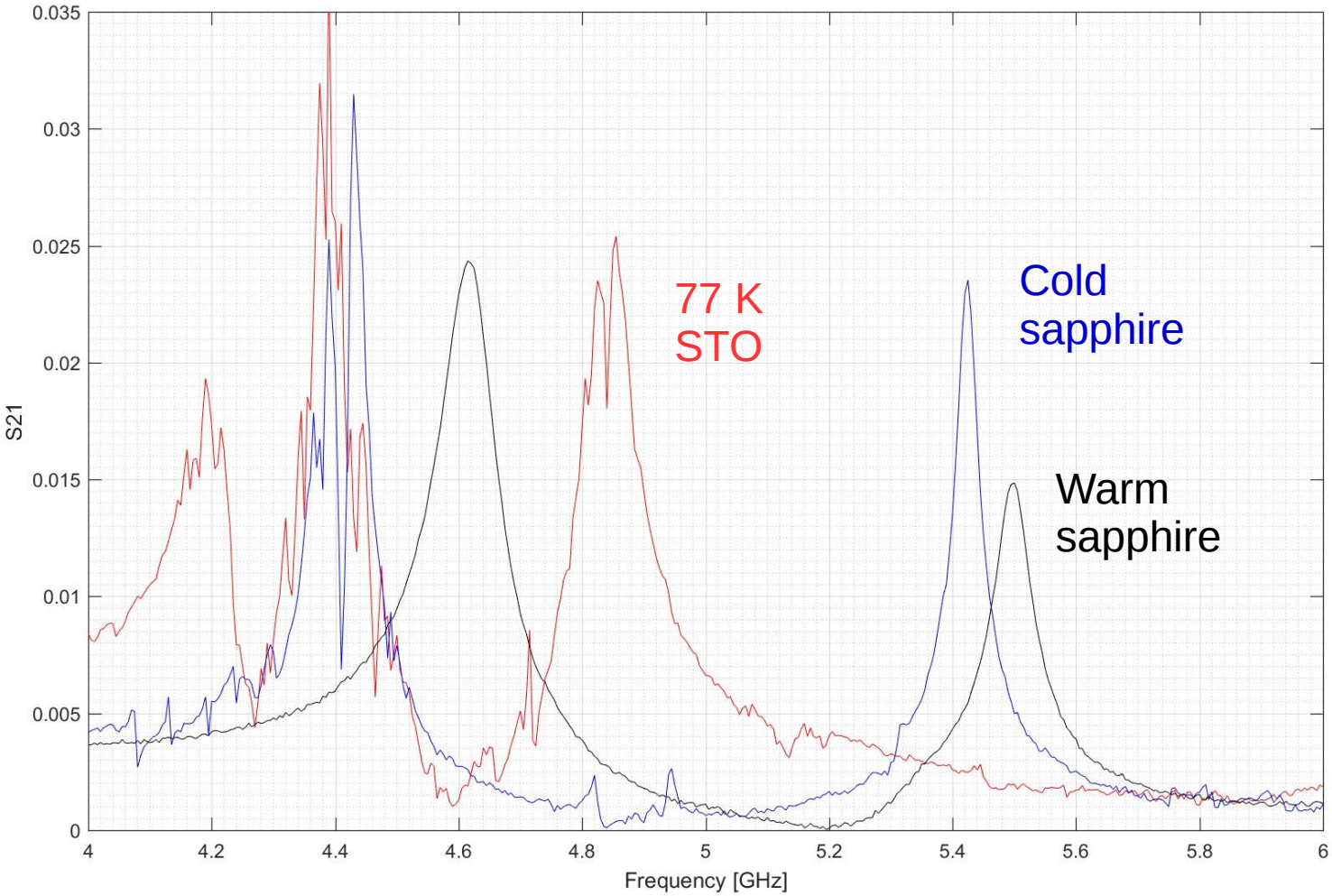


Measurement setup (FNAL Technical Division)



- Quantum Designs PPMS
- 1” bore diameter
- 1 K, 8 T

PRELIMINARY PPMS testing (no bias)



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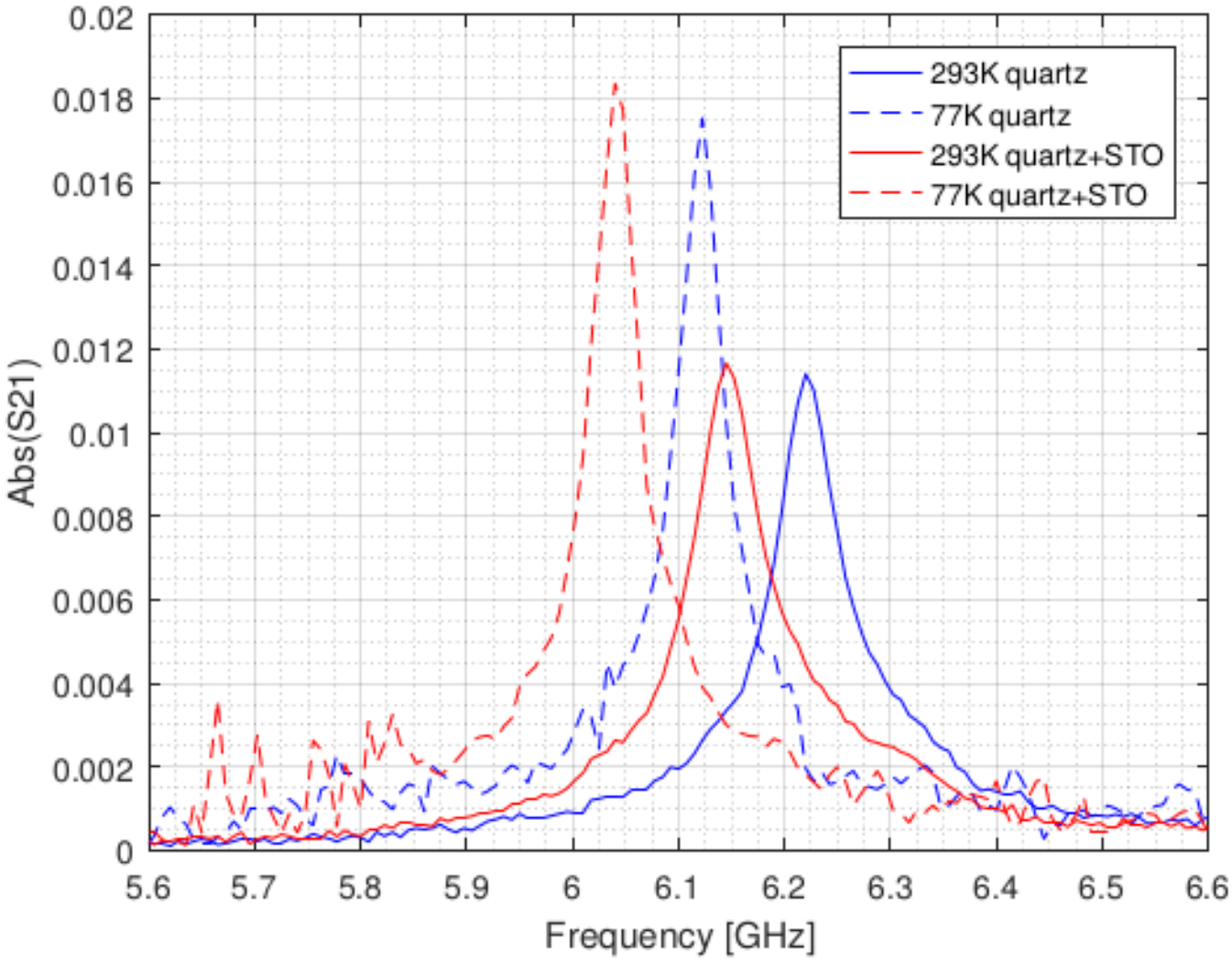
Quartz cryogenic performance (no bias)



Fermilab

Current status

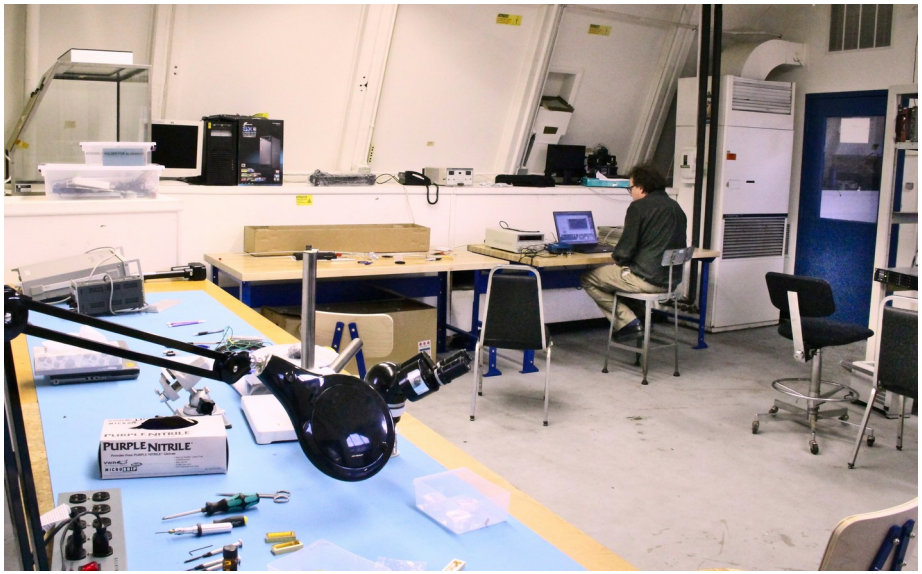
- We have a well-characterized resonator and multiple cryogenic test options.
- We have all required hardware in hand.
  - This includes a kV-class DC voltage supply with software control and leakage current protection.
- Measurement of film's dielectric strength is possible.
- Still needed: new samples with metallic coatings for DC bias electrodes.

Upcoming work

- Produce new samples with metallic coatings
- Demonstrate electric tuning using current setup
- Conceptual design for 3D implementation

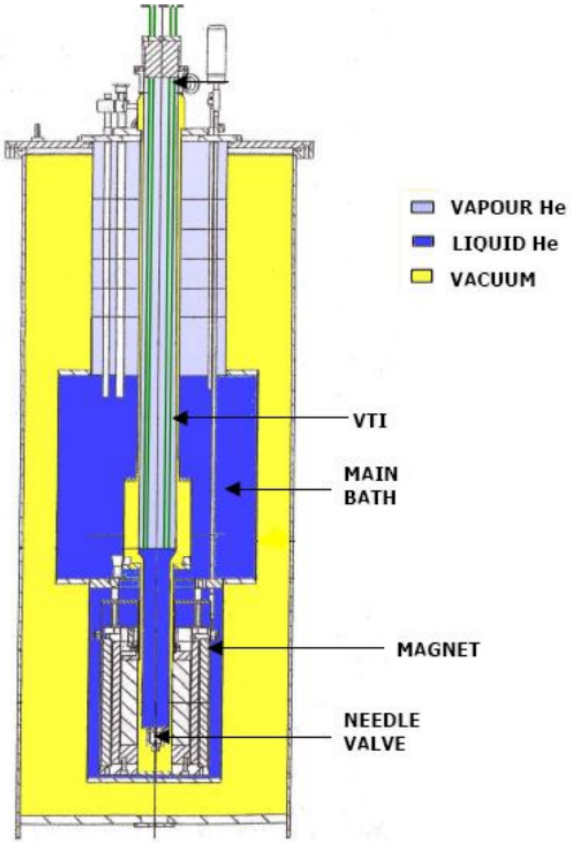
Supplemental slides

Lab space for axion R&D at FNAL



- 26 GHz network analyzer & assorted microwave hardware
- LN2 infrastructure
- Clean room access
- Engineering support

Low temperature / high field facilities



- FNAL Technical Division magnet R&D lab:
  - LHe Oxford cryostat
  - 17 T solenoid, 68 mm bore diameter