RF Absorber Studies at Cornell
Part 1

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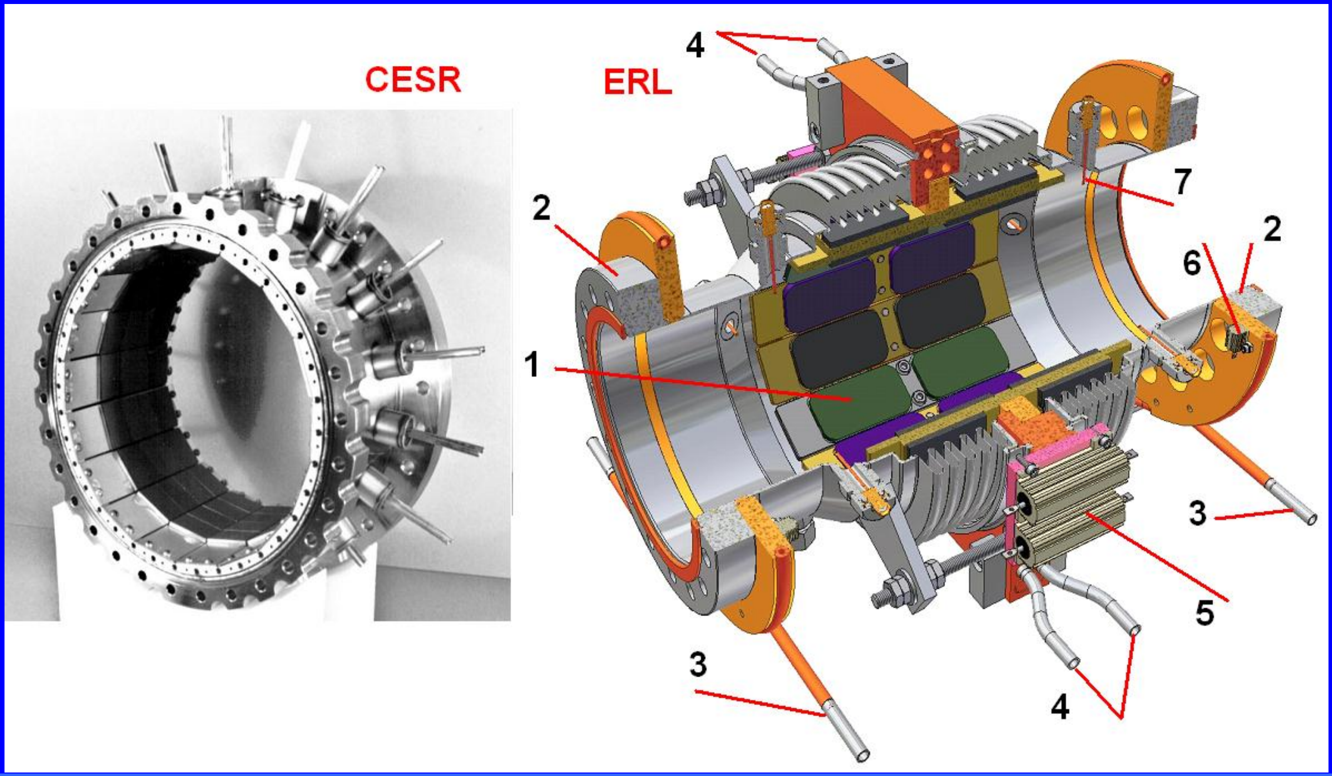
Outline

- ERL Injector HOM Load as the further development of the CESR HOM Load
- Results of measurements for ferrites and ceralloy at room and liquid nitrogen temperature
- As a result, 6 HOM Loads for the ERL Injector are working now
- Superficial absorbing materials free of ferrite shortcomings as a possible further development of HOM Loads

What is difference between CESR and ERL Injector HOM loads?

1) Temperature 80 K instead of 300 K to minimize the packing fraction, to ease the thermal transition to cavities at 2 K.

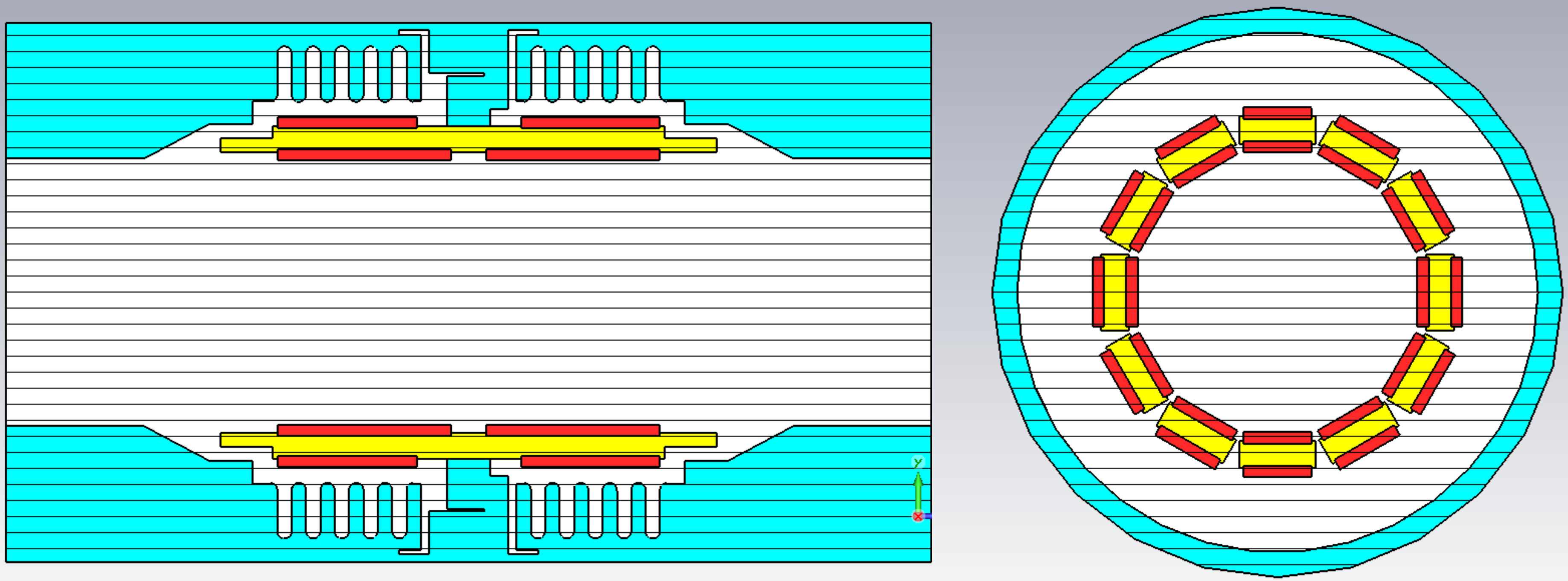
2) Shorter bunches, higher current, low emittance require damping over a large frequency range: 3 different materials of absorbers used.



1 – absorber plates,
…
3 – 5 K He cooling loop
…
4 – 80 K cooling loop
…

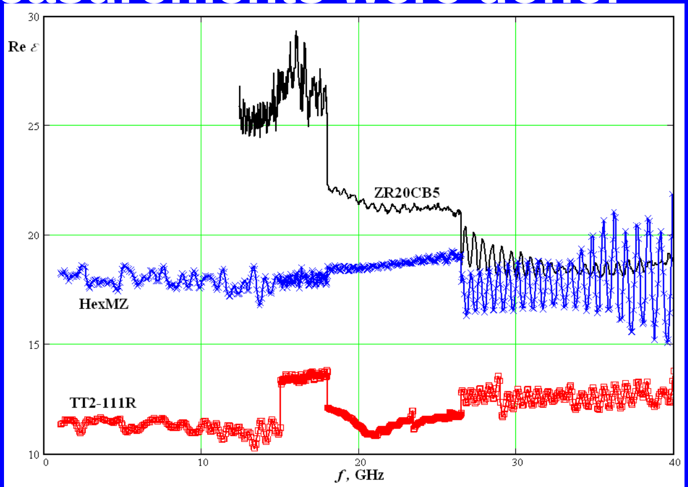
EPAC 2006, p.478

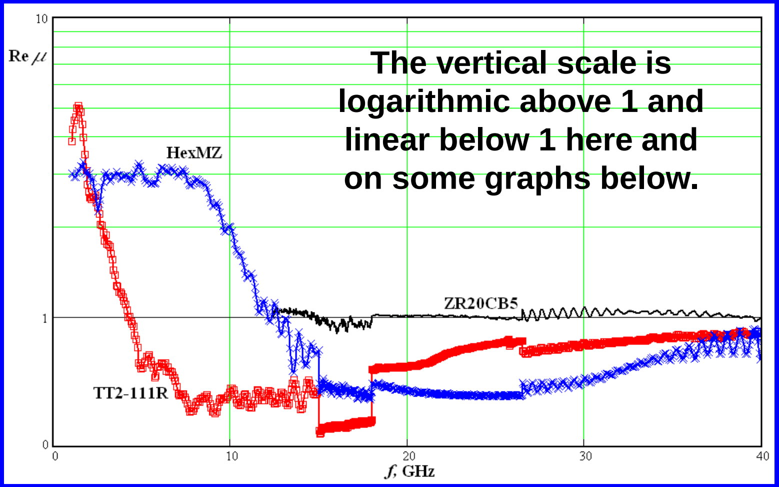
78 mm HOM Load, 3D MWS model

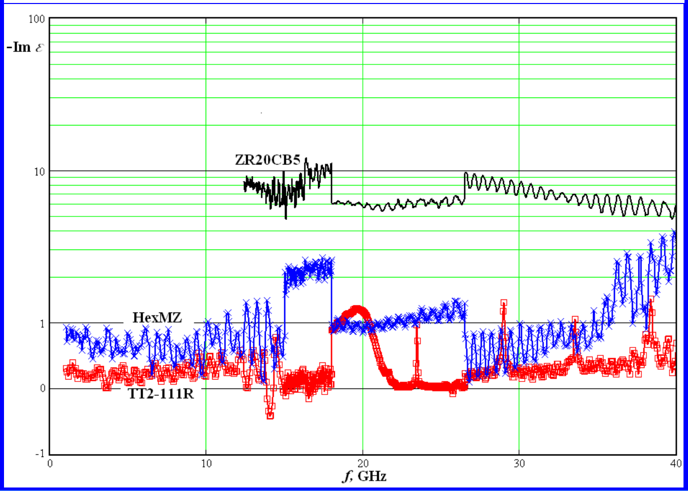


1) Temperature 80 K instead of 300 K…

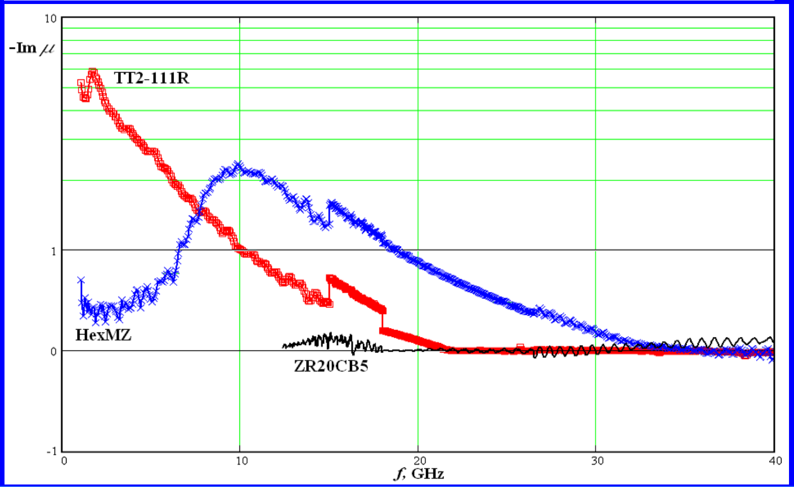
… measurements at this temperature are required, no data were available, measurements were done:







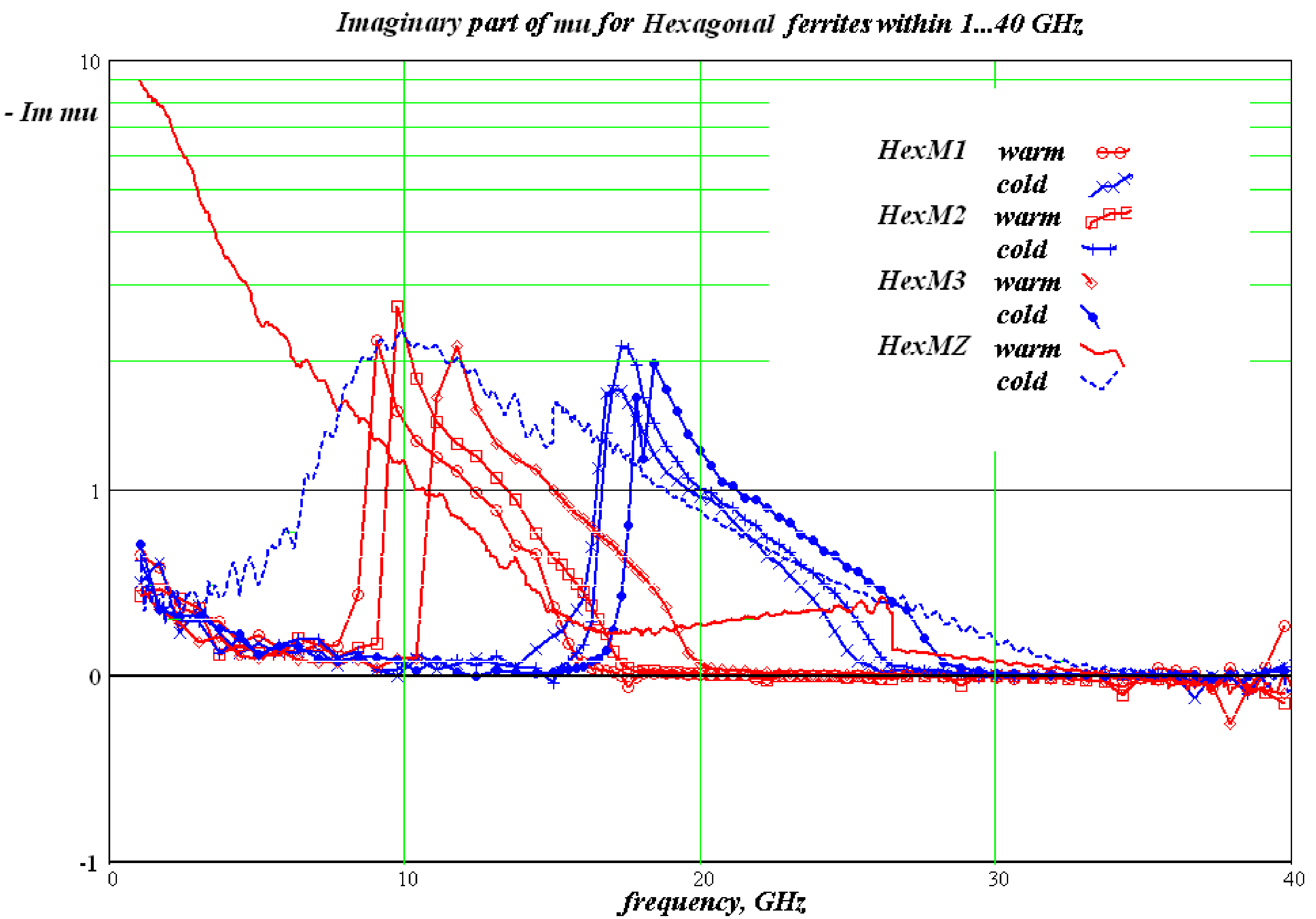
NIM A 557, p. 268 -271, 2006



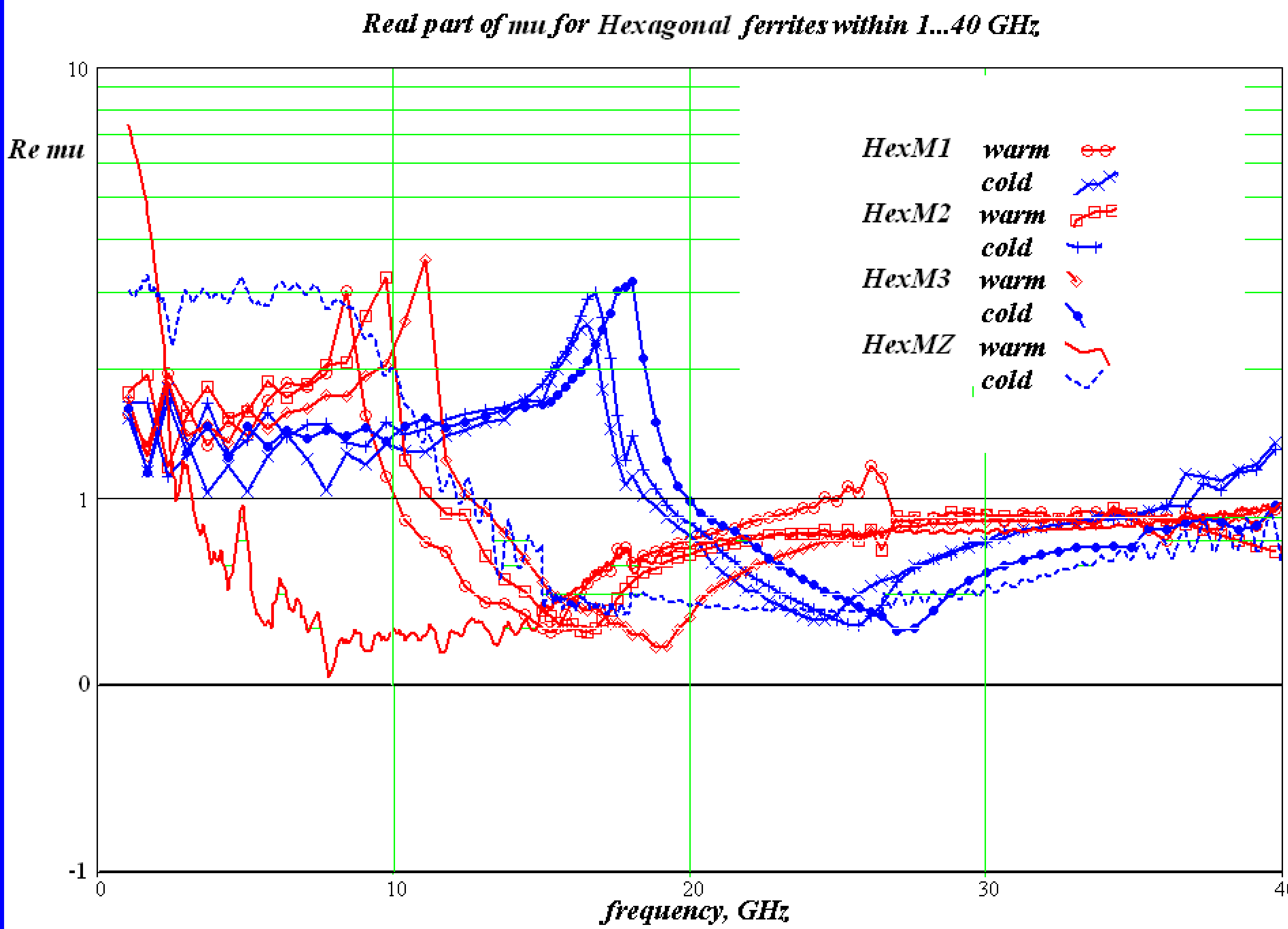
Curves are not very smooth because…

- **Data were measured with different samples in 4 frequency ranges: 1 – 12.4 GHz (coaxial line), 12.4 – 18, 18 – 26.5, 26.5 – 40 GHz (in the waveguides)**
- **Properties of samples change from batch to batch**
- **Samples of different ranges (sizes) have different errors of fabrication**
- **Some peaks are due to so called "ghost modes" – described in 1960 by Forrer and Jaynes, inner modes of samples excited due to their asymmetry. Their existence was checked by calculation and measurements with teflon samples having a known value of epsilon**
- **Reflections in the transmission line due to inaccuracy of assembling**

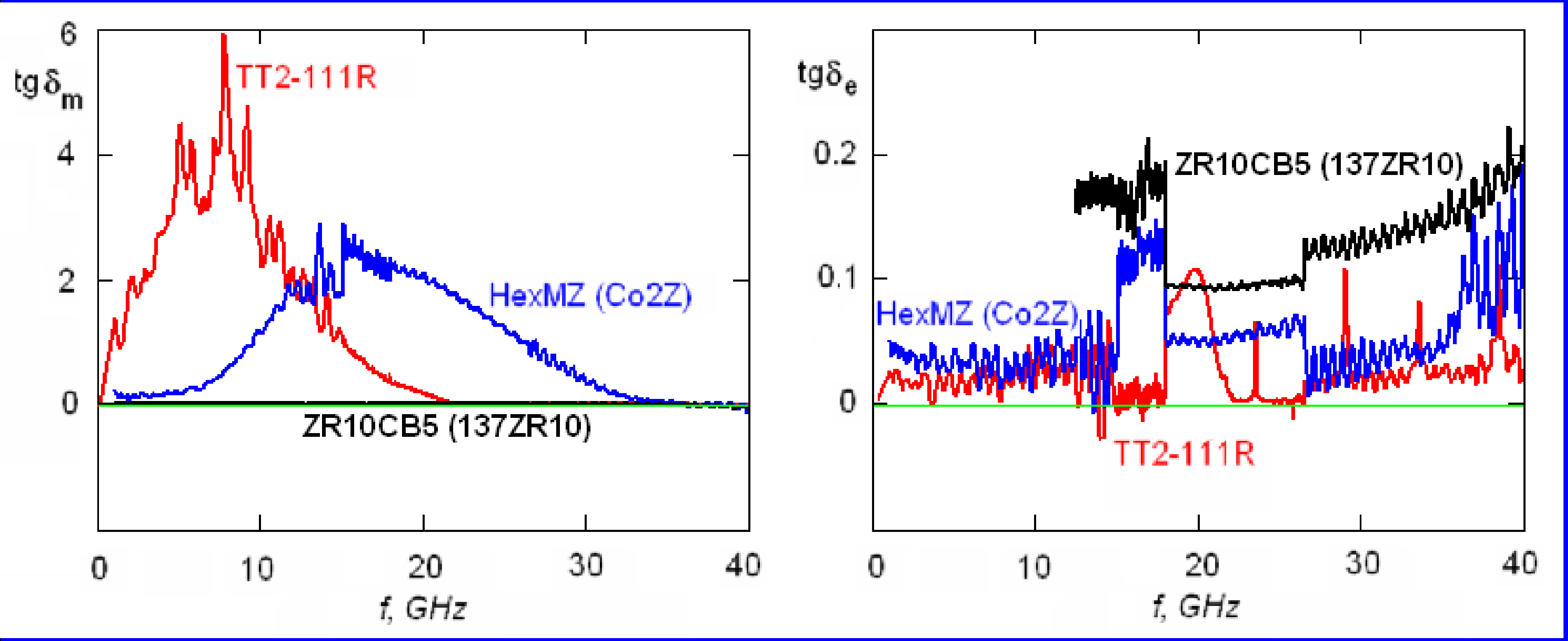
Shift of maximal absorption of the Hexagonal ferrites cooled from room temperature to 80 K



Real μ changes also



tanδμ and tanδε



Changed when cool

E/m properties of different materials change at 80 K, compared to room temperature in different ways:

- **Magnetic losses of C48-E1 and C48-E2 decrease at low frequencies when cooled and they change only slightly for TT2-111R. Besides, C48 are very brittle, and difficult to machining**

- **Resonant losses of Hexagonal ferrites shift about 10 GHz to higher frequencies that works for our purposes**

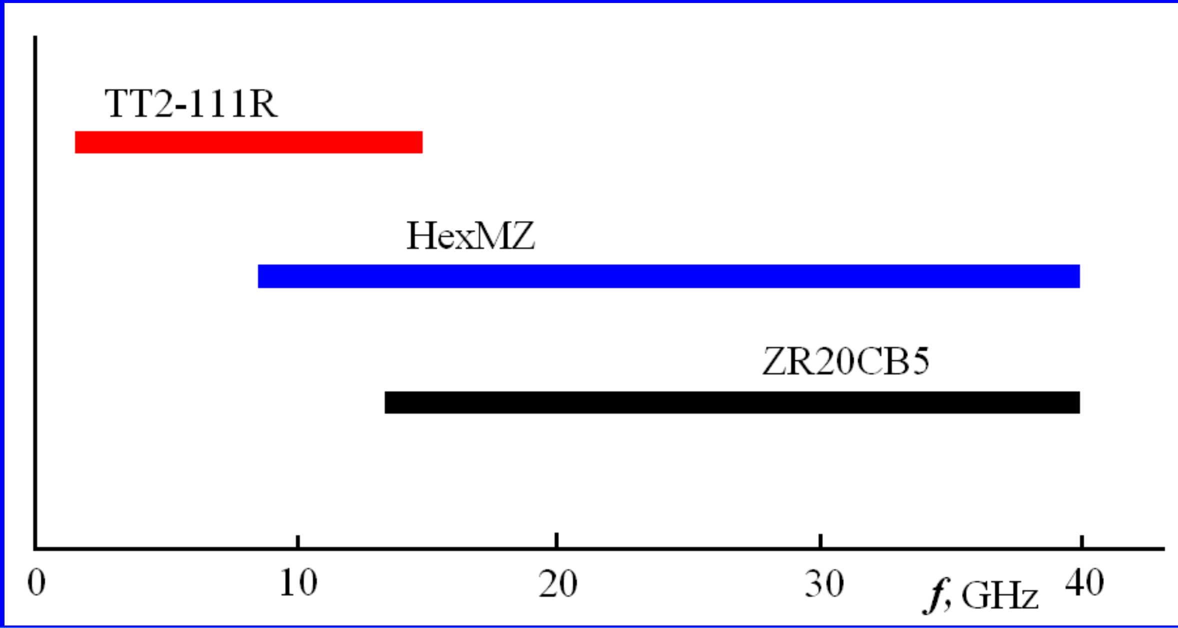
- **Losses of ceralloy practically do not change on cooling and keep up to highest frequencies**

2) …damping over a large frequency range

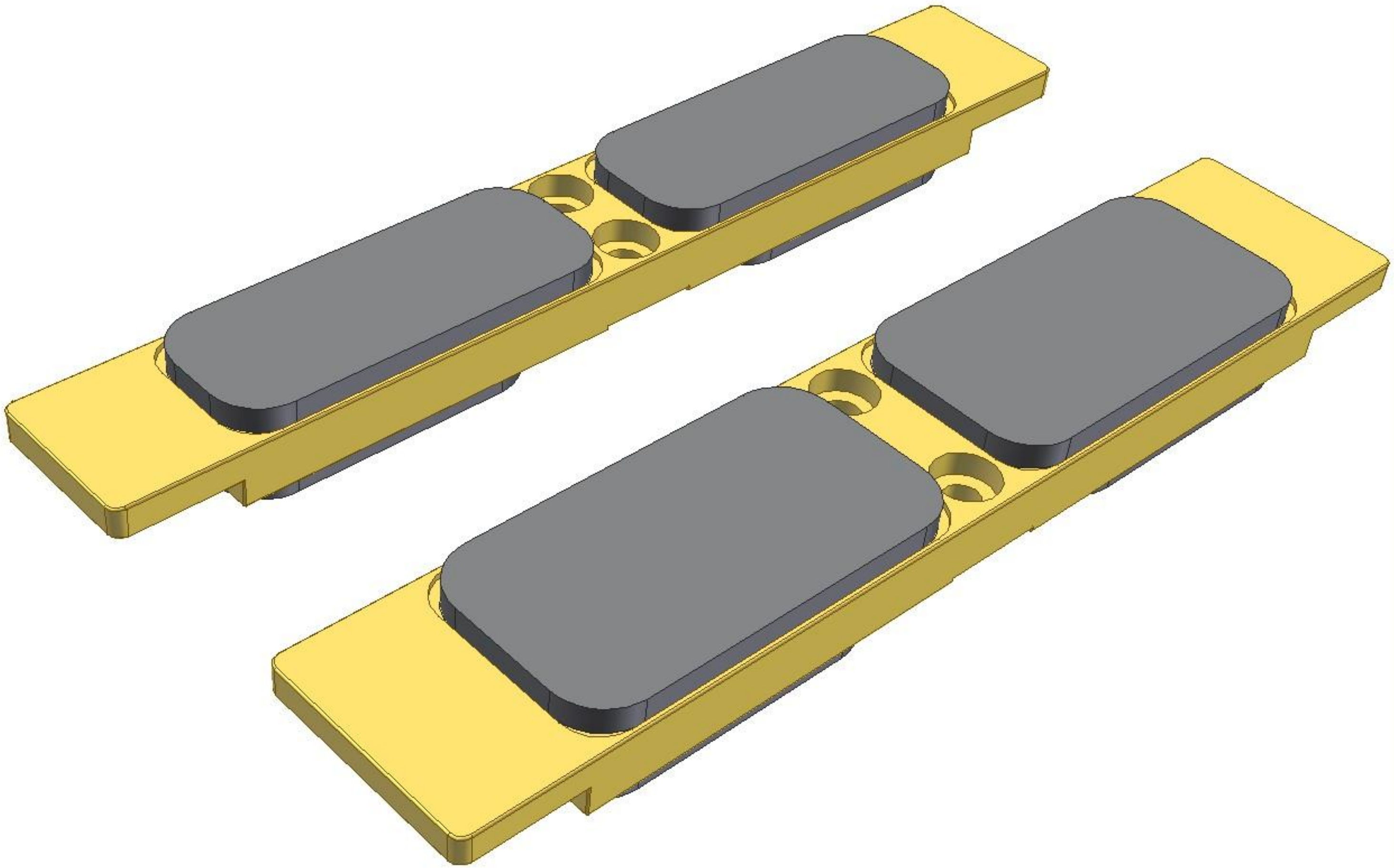
The tested materials fall into 3 groups:

- **ferrites TT2-111R, C48-E1, C48-E2 (Trans-Tech Inc)**
- **hexagonal phase ferrites HexM1, M2, M3, and MZ (Countis Labs)**
- **ceralloy ZR10CB5, ZR20CB5, Z7YL (Ceradyne Inc)**

3 materials were chosen, 1 from each group to cover a larger frequency range:

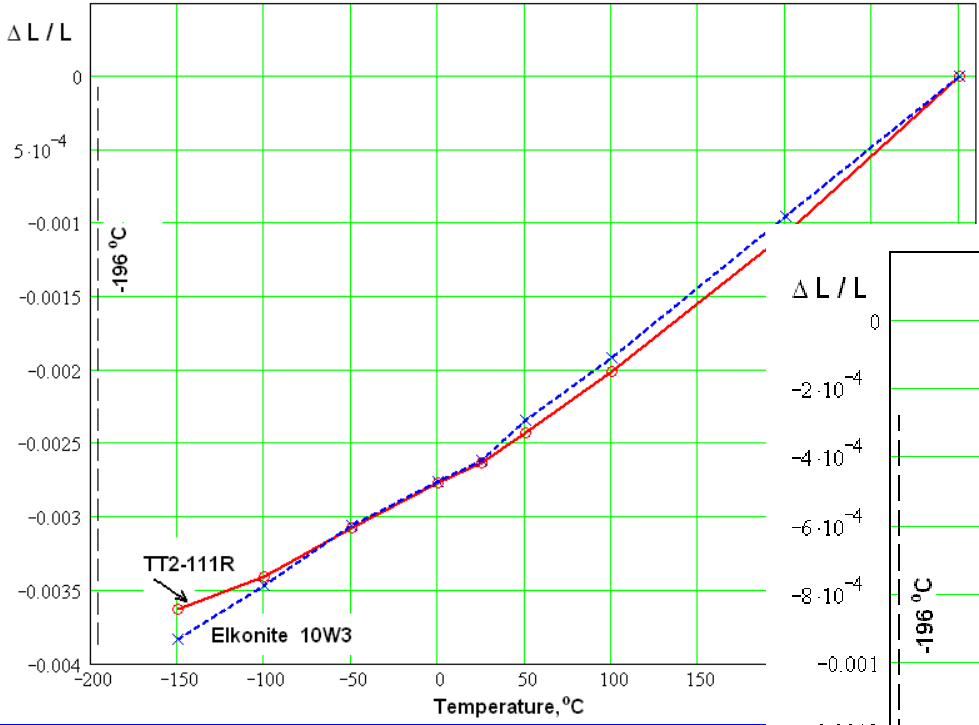


Absorber plates

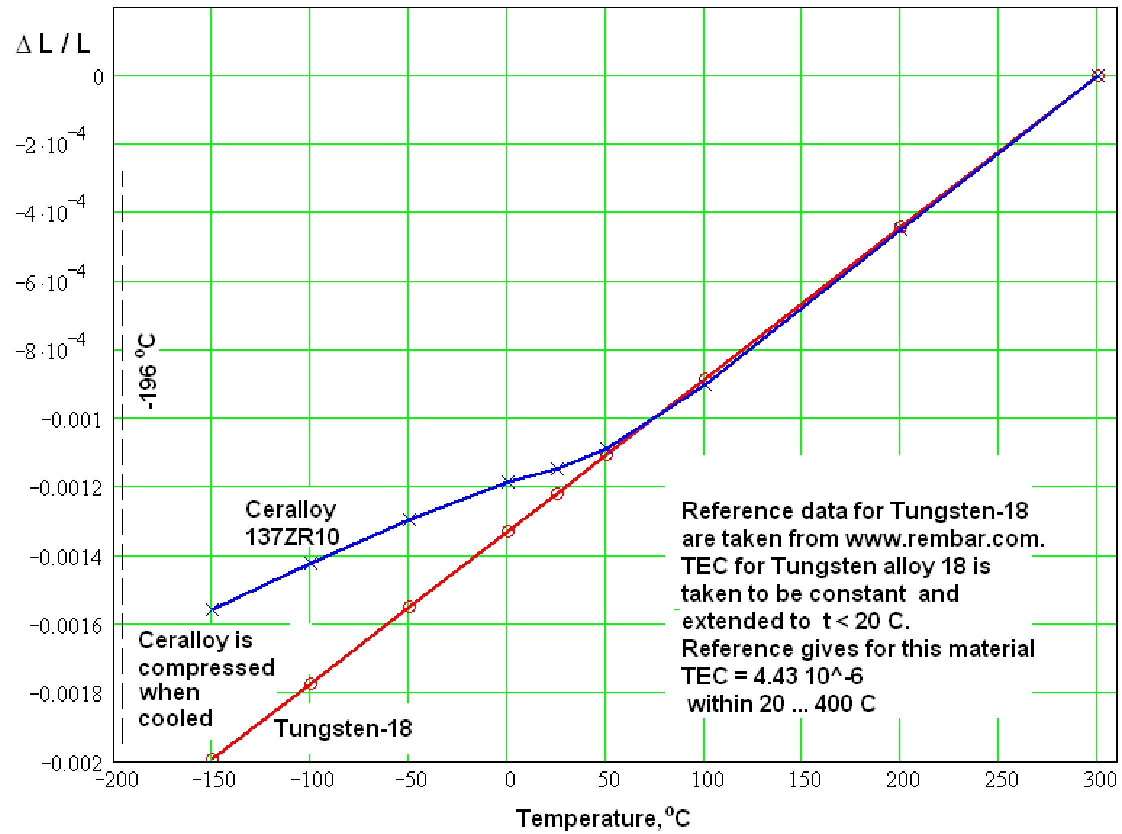


- **Absorbing tiles are placed on both sides of the plates.**
- **Loads of two sizes were produced: ID 78 and 106 mm**

Relative displacement for pairs "TT2-111R – Elconite 10W3" and "Ceralloy 137ZR10 – Tungsten-18" if they were matched at 300°C

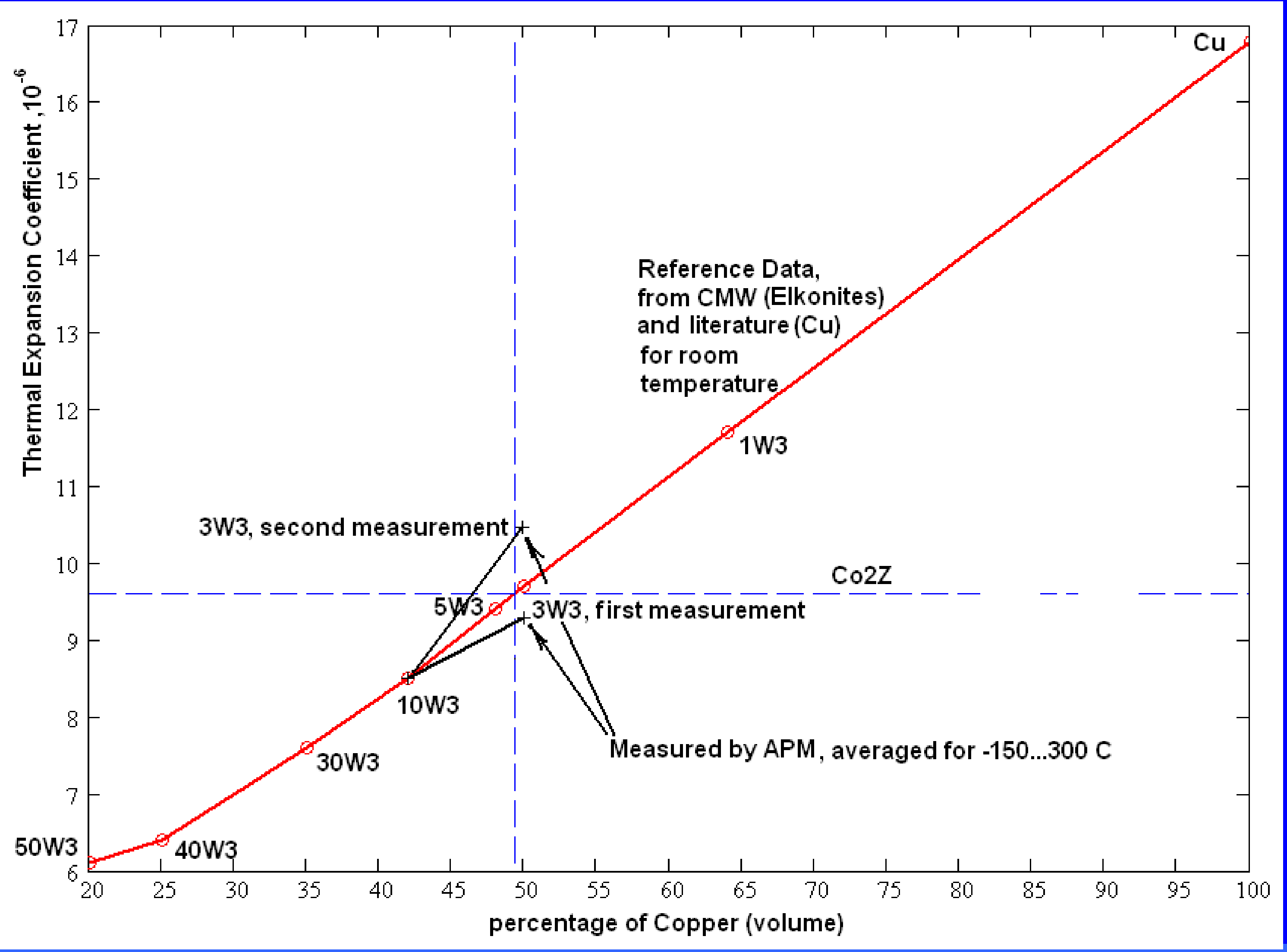


http://www.lns.cornell.edu/public/ERL/2007/ERL07-1/CTE_HOM.pdf



To prevent mechanical collapse the absorber should be compressed when cooled down

Elkonite compositions (Cu + W) can be used as a substrate for a broad range of lossy materials



Shortcomings of absorbing materials

Ferrites and lossy ceramics, used in HOM (higher order mode) loads for superconducting accelerators, have shortcomings such as

- **poor batch-to-batch reproducibility of electromagnetic properties (ceralloy),**

- **extremely low electric conductivity at cryogenic temperatures leading to accumulation of charge on the material surface (ferrites, ERL Injector),**

- **brittleness, which may cause contamination of the nearby SRF cavities by lossy dust (ferrites, ERL Injector), etc.**

A proposal to use a resistive material free of these shortcomings will be presented in another talk. Now, several words about measurements of RF conductivity of these materials.

Superficial absorbing materials

Difference between ferrites and lossy ceramic (ceralloy) on one hand and materials with high ohmic losses on the other hand is that in the former case the losses are volumetric and in the latter case – superficial.

Thermal conductivity should be much higher for surface absorbers to have the same temperature on the surface with same absorbed power .

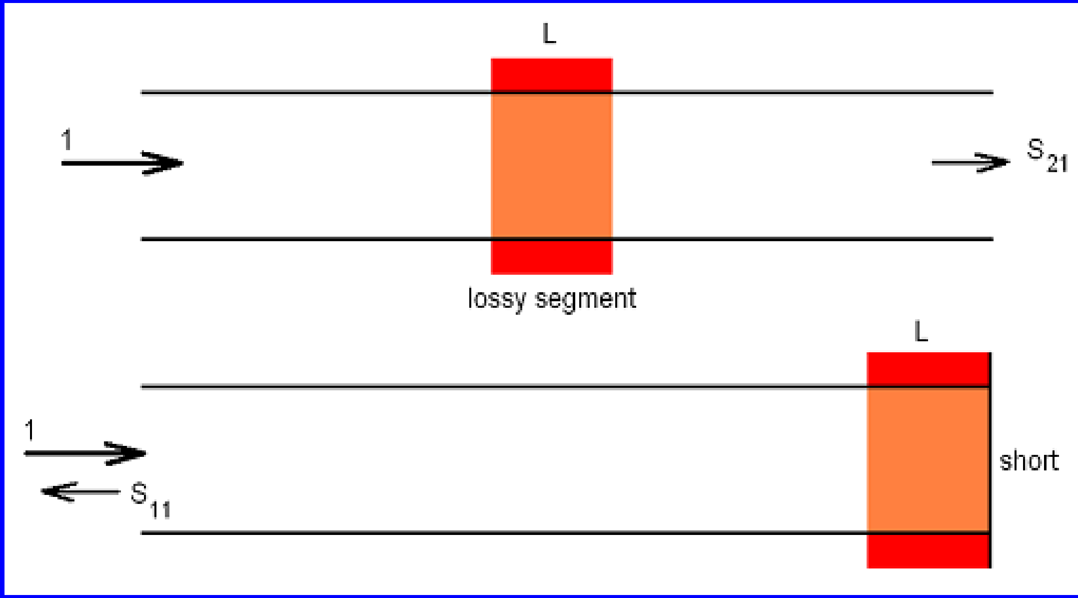
Thermal conductivity of the ferrites is about 5 W/m·K, the plates have thickness 1/8 inch.

A new composite material consisting of silicon carbide reinforced by carbon fibers is, possibly, free of many shortcomings inherent to ferrites. Its TC is 30 W/m·K at 50 K and 160 W/m·K at 293 K that is only 2.5 times less than of copper and 10 times higher than stainless steel at room temperature.

Superficial absorbing material - Cesic

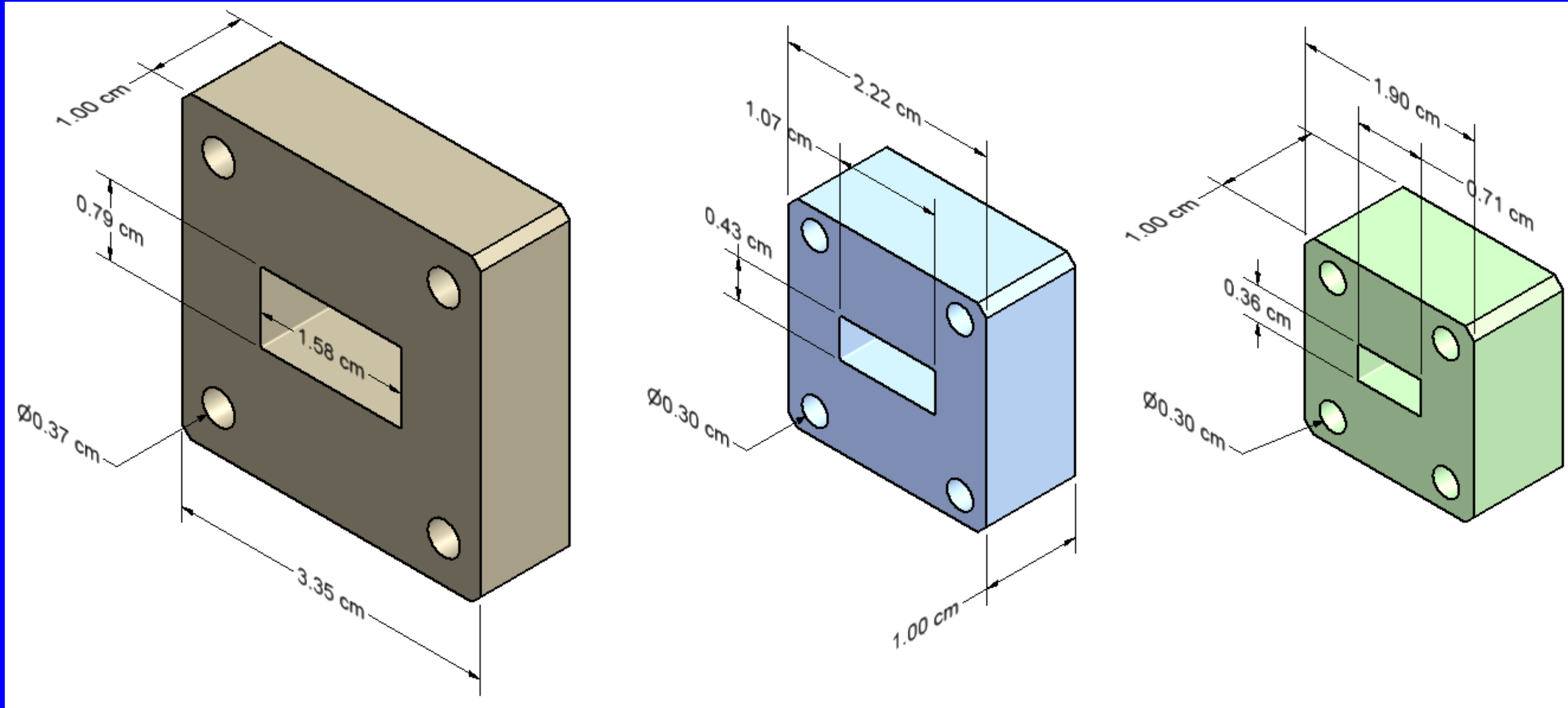
The trade name for this C/Si material produced by ECM (Germany) is Cesic®. It has high mechanical and vacuum properties and was used in production of space telescopes.

We measured RF conductivity of this material up to 40 GHz using the same set up that was used for ε/μ measurements. To increase sensitivity of the measurements we also used double passage of the RF wave through the lossy sample. Measurements were done at room temperature.



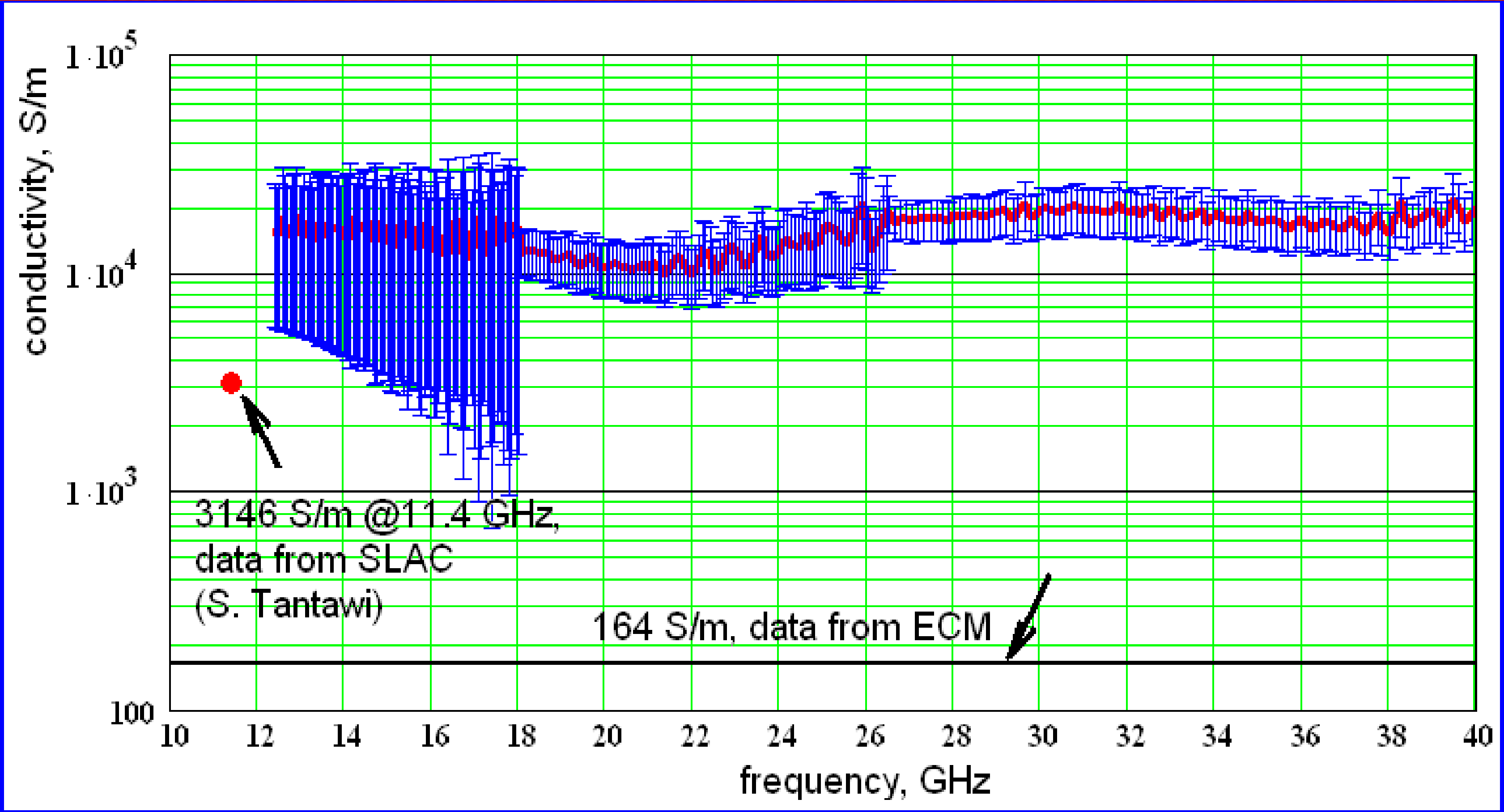
http://www.lns.cornell.edu/public/ERL/2010/ERL10-1/ERL10-1.pdf

SiC (CeSic) samples for RF and vacuum tests



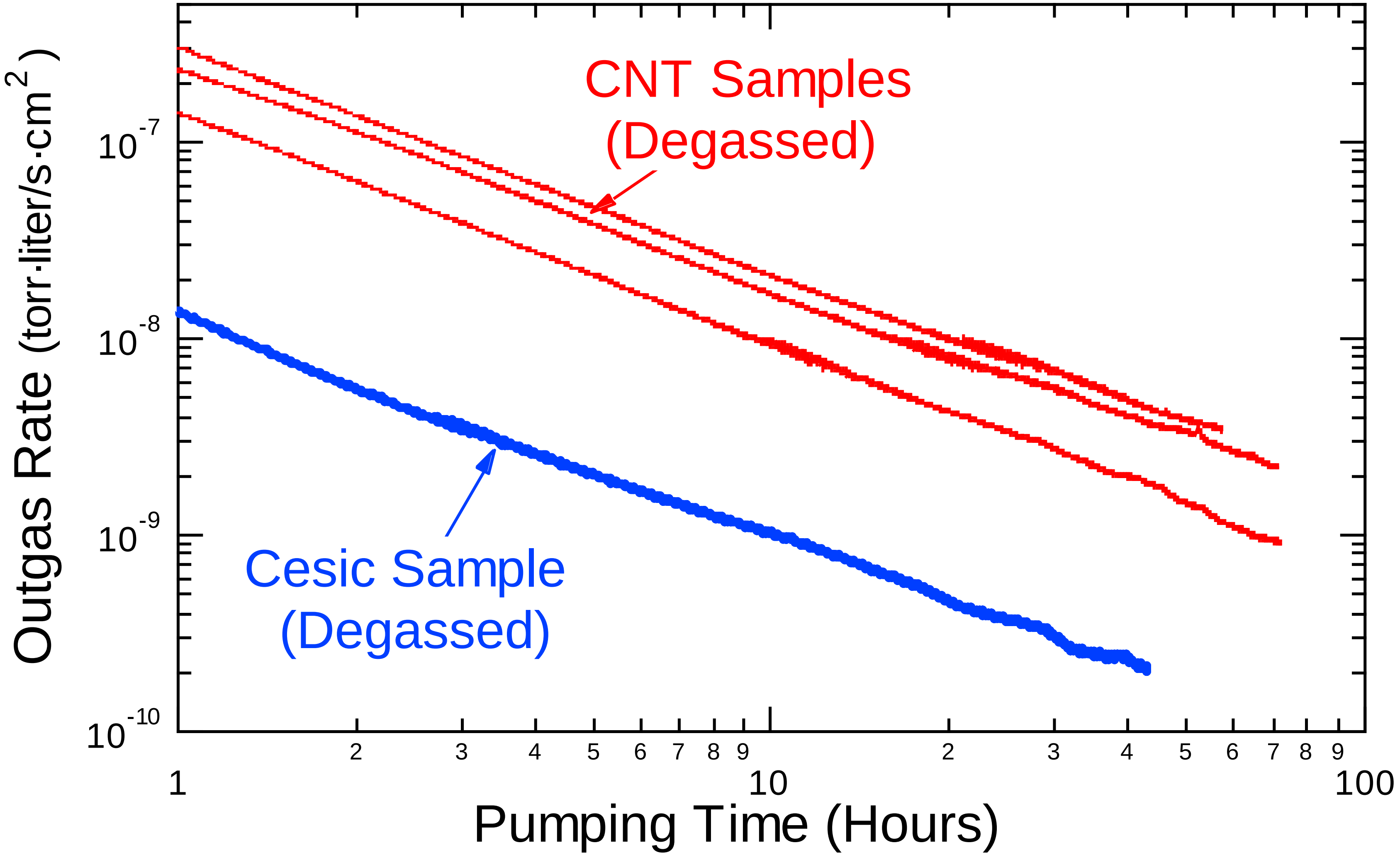
WR62	WR42	WR28
Surface Area = 41.8 cm^2	Surface Area = 24.0 cm^2	Surface Area = 20.3 cm^2

Electric conductivity of Cesic vs frequency



We take it as constant, 15 kS/m.

Measured outgassing rate of the Cesic and the CNT material.



Comment to the previous slide

- To evaluate vacuum compatibility of the CESIC and CNT (Carbon Nano Tubes) materials, their outgassing rates were measured using standard throughput method. The measured outgassing rates are given in the Figure. All the rates were measured with samples at room temperature. Much lower outgassing rates are expected when these materials are at cryogenic temperatures. As expected, the degassed (150°C/24hr vacuum bake) samples exhibit significantly faster pumping down and lower outgassing rates. The data also indicate that the CNT material has much higher outgassing rate, which may be due to the trapped gas in the nano-tubes.

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