Electromagnetic characterization of Amorphous Carbon in the sub-THz

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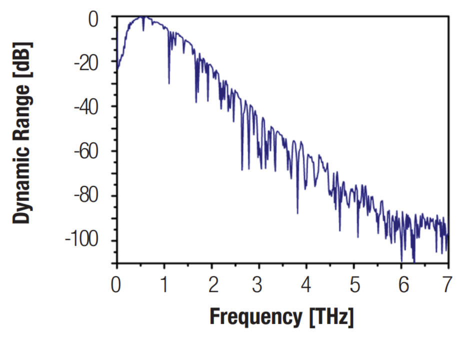
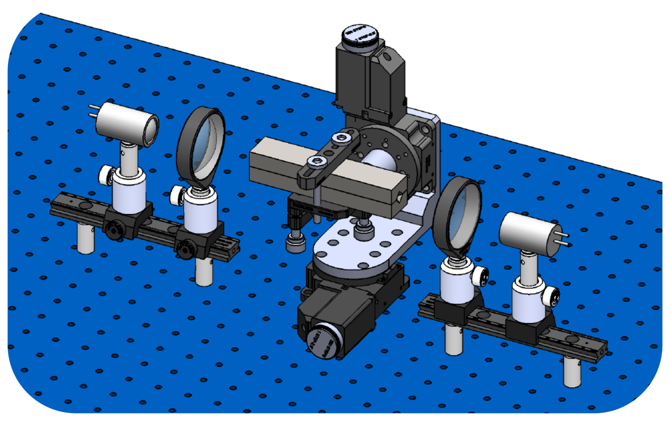
Abstract

Modern accelerators and light sources often require special treatment of the vacuum chamber surface in order to avoid undesirable effects and to maximize machine performance. Coating with Non Evaporable Getter (NEG) and Amorphous Carbon (a-C) has been extensively tested and used with very effective results since it allows to reduce the secondary electron yield (SEY) of the pipe walls due to electron cloud and to avoid the relevant beam instability. An electromagnetic characterization a-C coating is therefore fundamental to build a reliable impedance model. Our characterization method is based on time domain measurements of an electromagnetic wave passing through a tailored half-waveguide, closed with a bulk piece where the coating is deposited. This configuration is designed to have a homogeneous coating thickness large enough to allow a good signal-to-noise ratio but also to avoid peel-off and blistering. The electromagnetic characterization is performed in the frequency range from 0.1 to 0.3 THz.

The method

Evaluation of the **signal attenuation** inside a DUT with coating deposited. ⇨ **Electromagnetic characterization** of coating material.





Time-Domain THz Spectrometer

System specifications:
- Spectral Range: > 3 THz
- Dynamic Range > 70 dB
- Scanning Range ~ 300 ps
- Spectral Resolution < 3.5 GHz

⇨

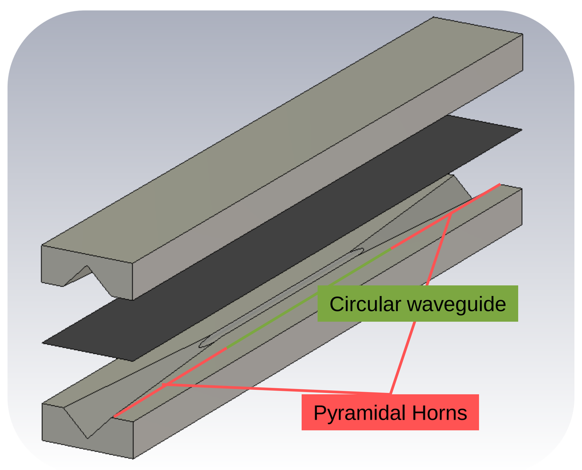
Upgrade:
- > 5 THz
- > 90 dB
- ~ 850 ps
- < 1.5 GHz

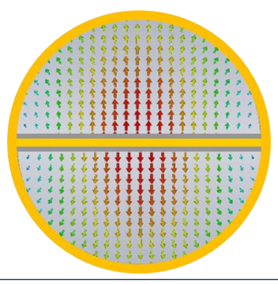
Recent results → NEG

Analytical model
Comparison with CST simulations

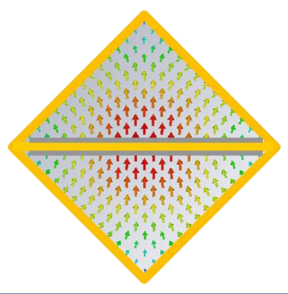
$$\alpha = \frac{1}{2}\frac{Re(Z_S)}{Re(Z)}\frac{\int |H_{tan}|^2 ds}{\iint |H_t|^2 dS}$$

Z_s: surf. char.imp.
Z: mode char.imp.
H_{tan}: tang. mag. field
H_t: trans. mag. field



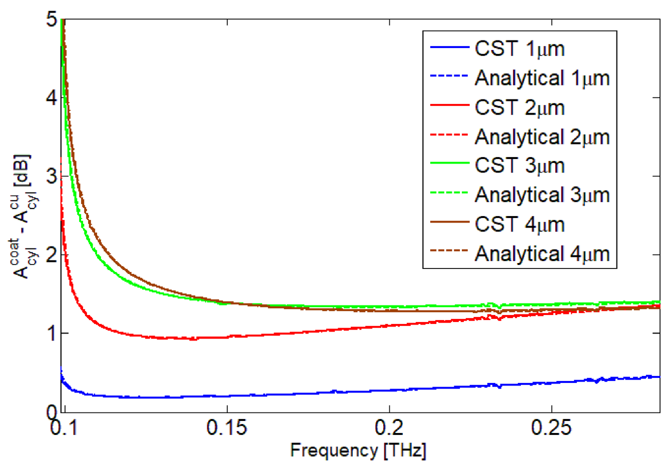


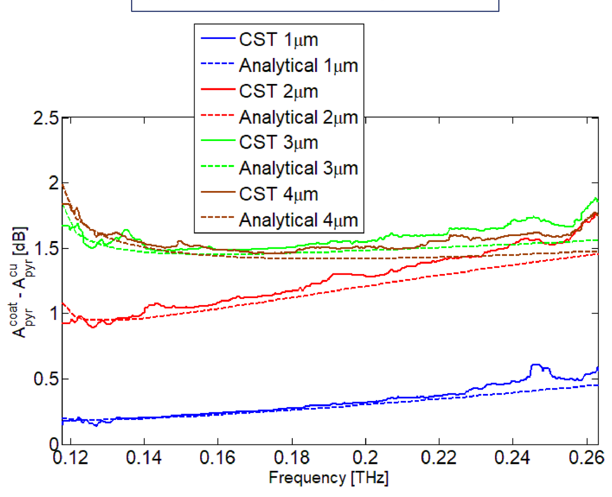
Conductivities
$\sigma_{cu} = 6{\cdot}10^7$ S/m
$\sigma_{NEG} = 3.5{\cdot}10^5$ S/m

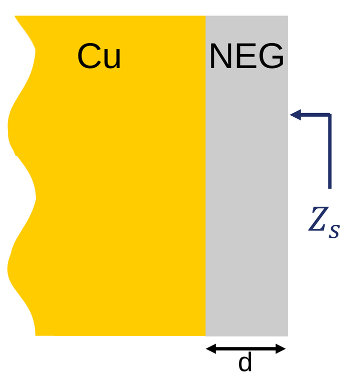


Circular waveguide
length: 42mm
radius: 0.9mm

Pyramidal transition
length: 39mm
side: 6mm → 1.2728mm

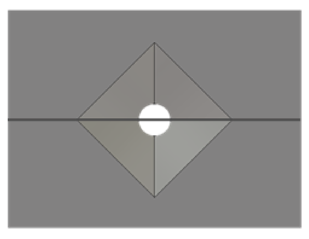


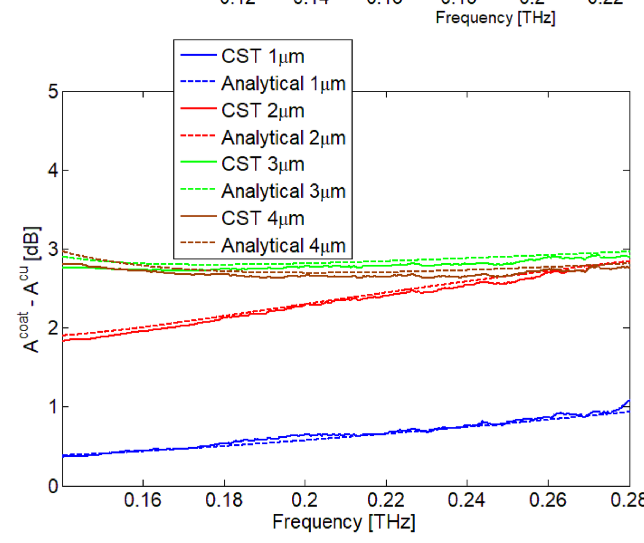




$$Z_s = Z_{NEG}\frac{Z_{Cu} + jZ_{NEG}tg(k_{NEG}d)}{Z_{NEG} + jZ_{Cu}tg(k_{NEG}d)}$$

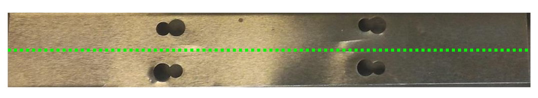
Entire structure
Circular waveguide & Pyramidal transitions

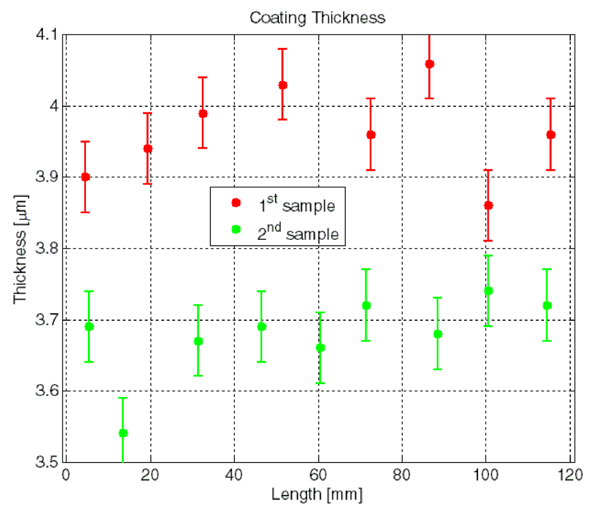




Thickness and composition
XRF measurements

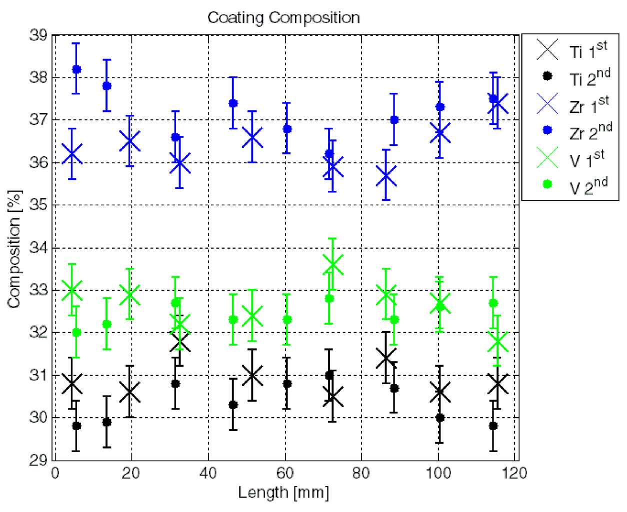
at CERN ATELIER DE TRAITEMENTS DE SURFACE



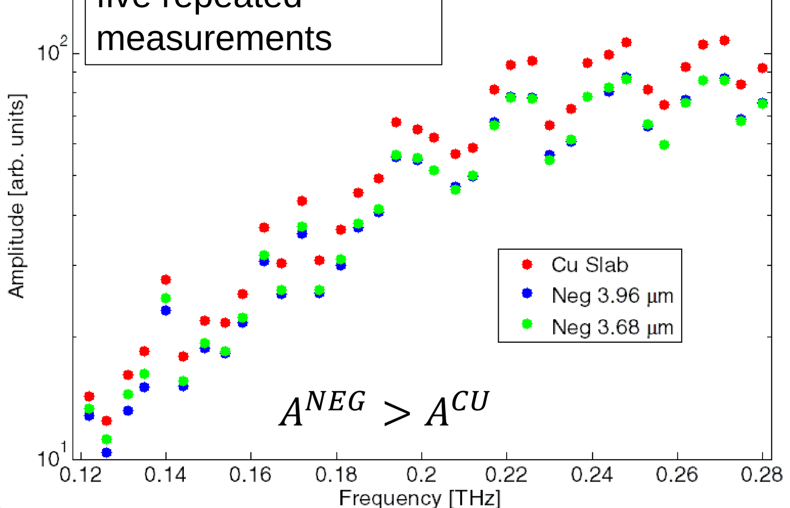


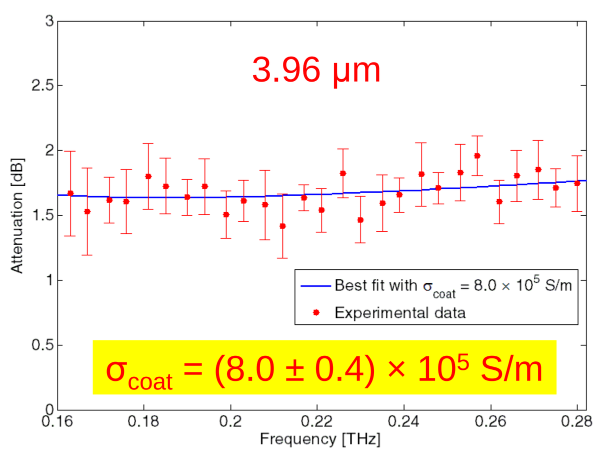
3.96 μm

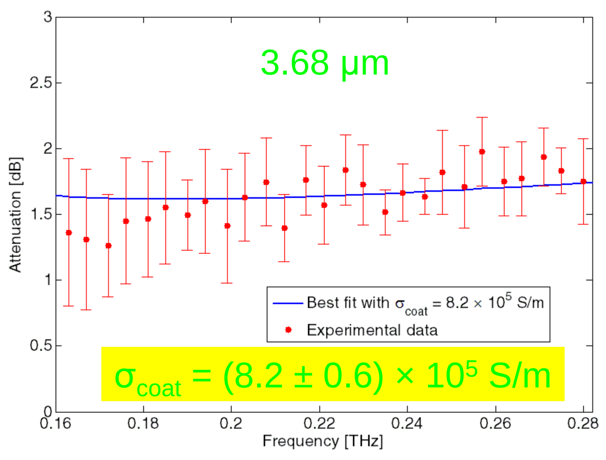
3.68 μm



Measurements
five repeated measurements







$\sigma_{coat} = (8.0 \pm 0.4) \times 10^5$ S/m

$\sigma_{coat} = (8.2 \pm 0.6) \times 10^5$ S/m

Novel measurement technique for the electromagnetic characterization of coating materials in the sub-THz frequency range.

Andrea Passarelli, Hannes Bartosik, Giovanni Rumolo, Vittorio Giorgio Vaccaro, Maria Rosaria Masullo, Can Koral, Gian Paolo Papari, Antonello Andreone, and Oliver Boine-Frankenheim
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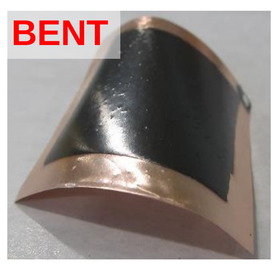
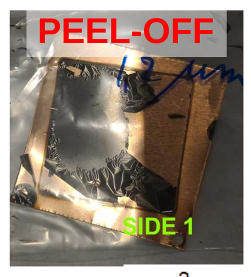
Next step → a-C

DC measurements
Serway, Raymond A., and Jerry S. Faugh. *College Physics. 6th Edition*. Belmont, CA: Thomson, 2003.

⇨ $\sigma = 2.8{\times}10^4$ S/m



a-C deposition problems on slab



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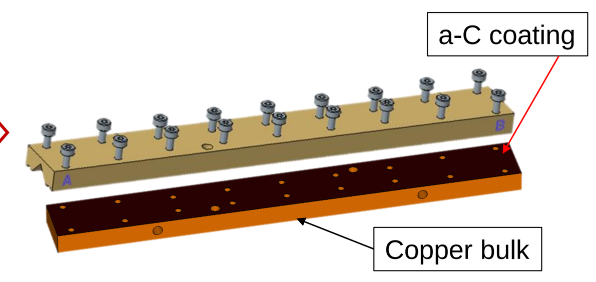
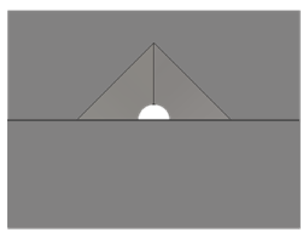
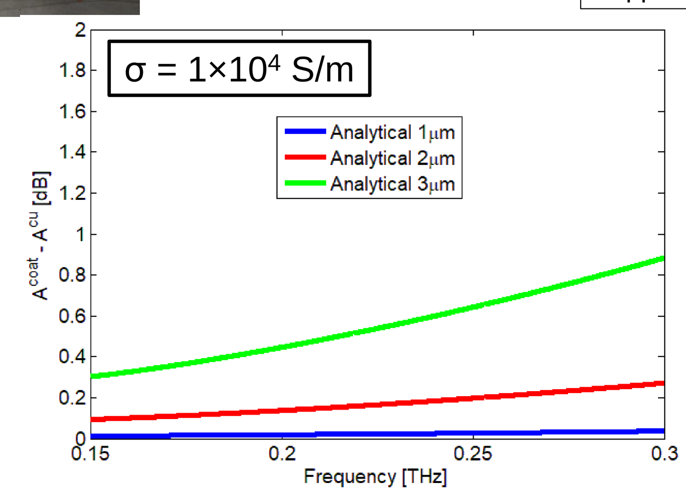
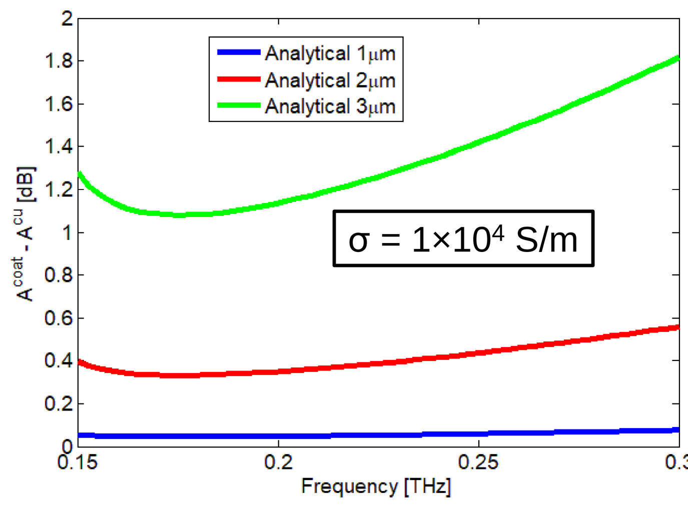


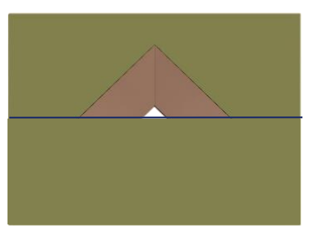
Circular Waveguide Pyramidal transitions
Same waveguide used for NEG characterization

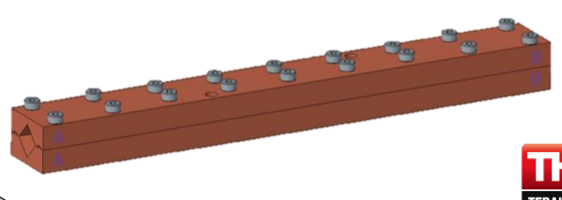


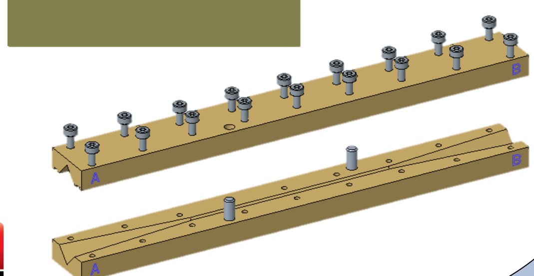




Diagonal Waveguide
length: 62mm
side: 1.1mm
Pyramidal transitions
length: 39mm
side: 6mm → 1.1mm







Conclusions & Outlook

Conclusions
- **Reliable analytical model** for the conductivity retrieval.
  - Good agreement with CST Frequency Domain solver.
- **Successful measurement campaign**: reliable, handy and inexpensive method to evaluate the electromagnetic properties of samples under test
- The advantages of the setup with the central coated slab are:
  - inherently simplified manipulation of the overall setup.
  - possibility to have a uniform deposition on the slab.
- **Upgrade** with respect to NEG measurement device:
  - more performing signal generator.
  - simpler and more accurate guiding system manufacturing.
  - change of waveguide setup to overcome the demanding thickness requirement in a-C deposition.

Outlook
- a-C sputtering deposition (5 μm already coated in a first test, but bent).
- Measurements with a-C coated slab are planned very soon.

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