

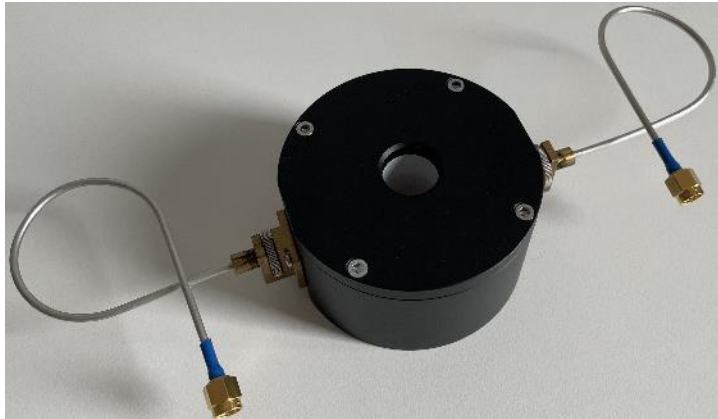
TUMA21

***Dielectric and Cavity Resonators
for Accurate Characterization
of Liquids in the 1-50 GHz Frequency Range***

Speaker: Marzena Olszewska-Placha
QWED company (Booth #2447)
(www.qwed.eu)

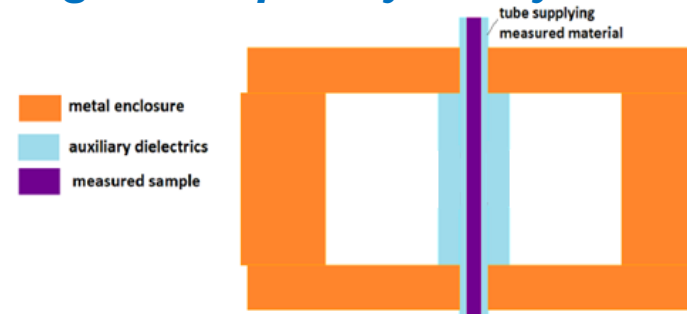
Resonant methods are proven to be **the most accurate** among microwave material characterisation methods

Low frequency dielectric resonator cavities



Dielectric resonator cavity at 1 GHz

Higher frequency cavity resonators



24-GHz Cavity resonator
(with fused silica tube, rubber tube and syringe)

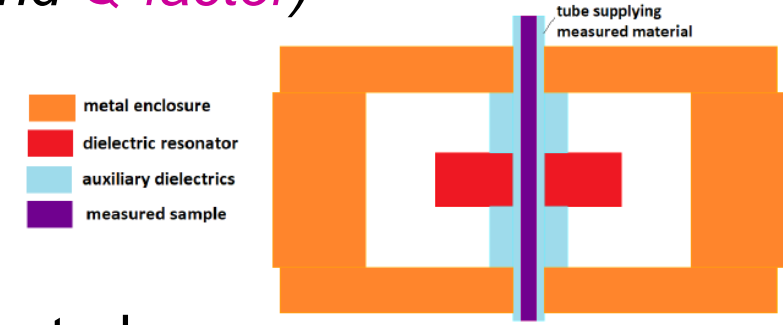
Fabry-Perot Open Resonator



Single solution for 15-50GHz

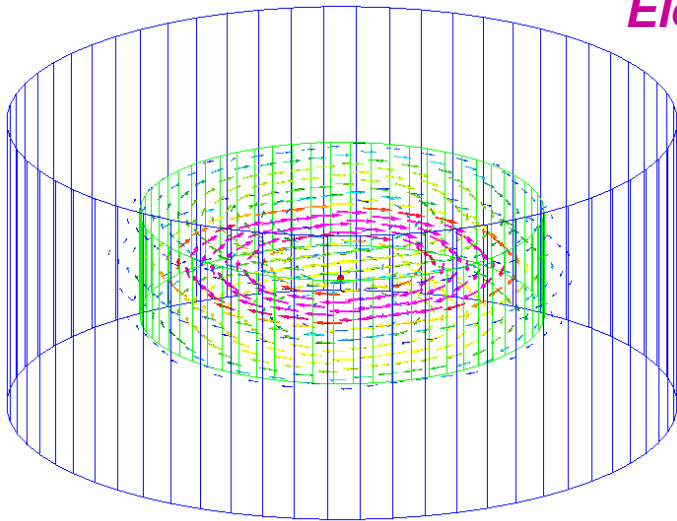
Measurement methods

- $TE_{01\delta}$ resonance mode (described with *resonant frequency* and *Q-factor*)
- Electric field mostly confined within the dielectric pill
- Circumferential electric field
 - no issues with galvanic connection of the lid
- Zero electric field at $\rho=0$
 - no risk of suppressing resonance if lossy sample is inserted

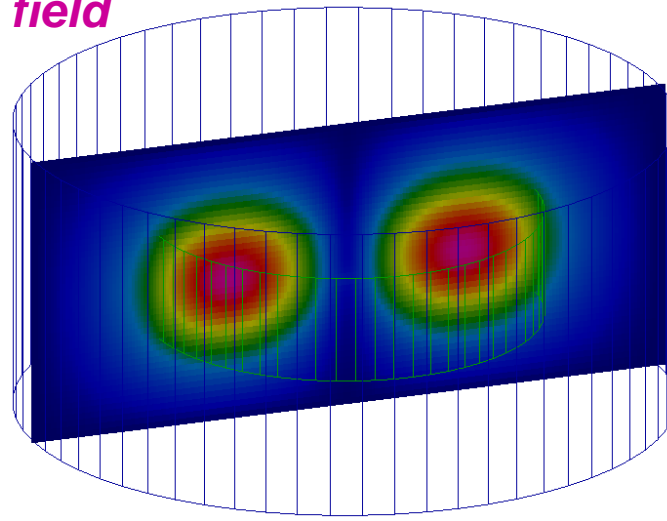


*Resonance mode within dielectric resonator cavity **

Electric field

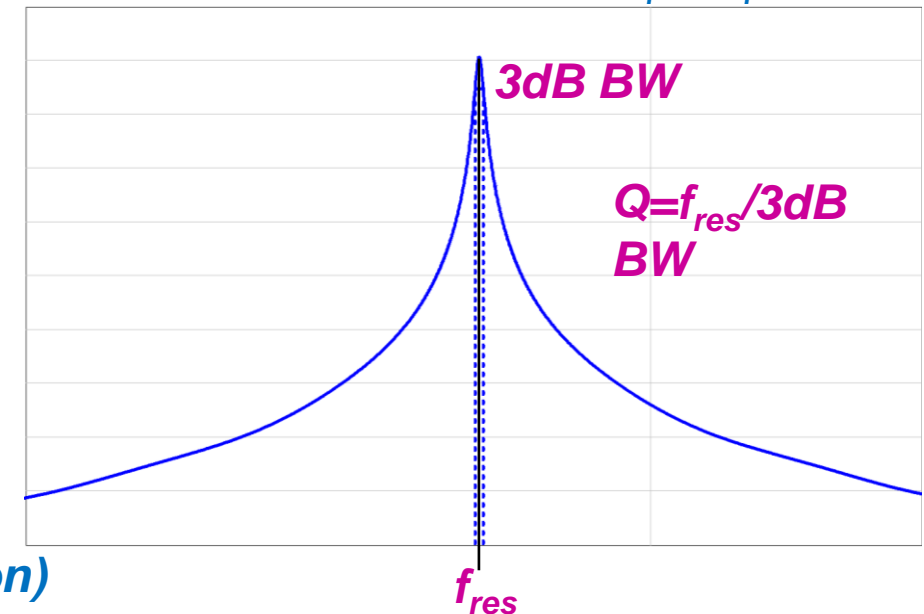


Vector view



Amplitude view (cross section)

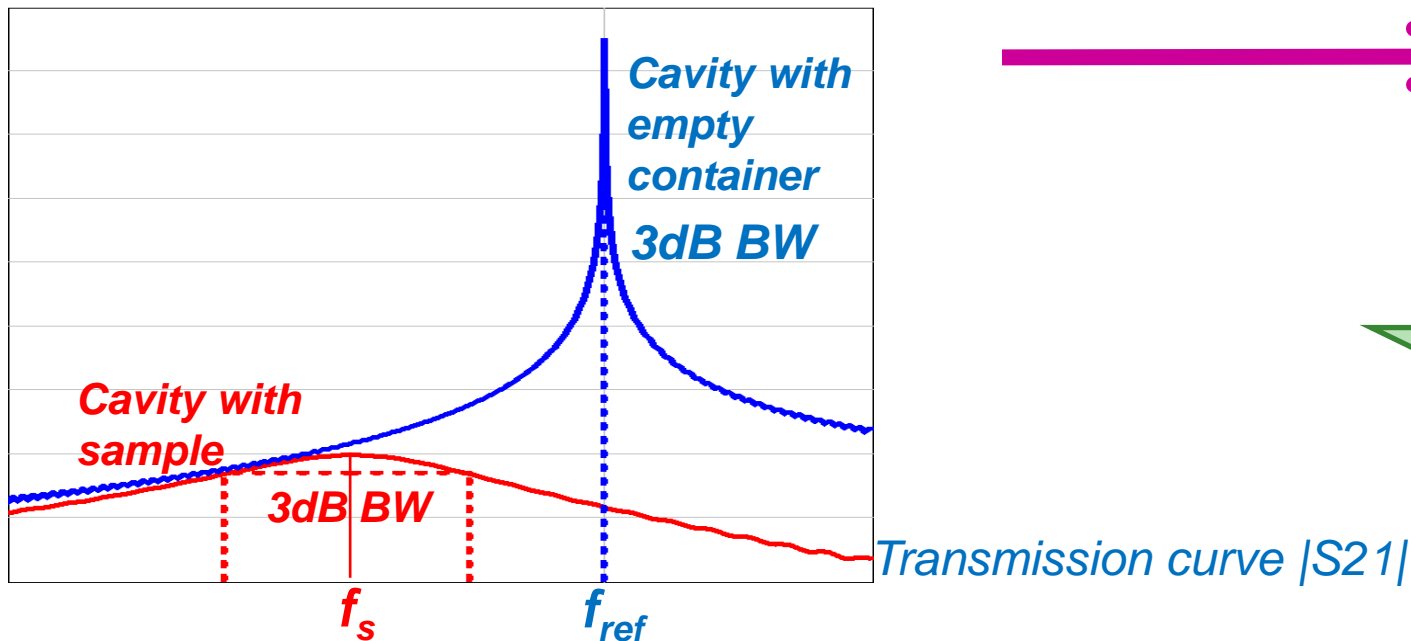
Transmission curve $|S_{21}|$



* Obtained with QuickWave 3D software

Measurement methods (2)

- Two/three stage measurement
- Reference measurement – **cavity with empty container** (f_{ref} and Q_{ref})
→ the inner diameter of the container/container needs to be precisely calibrated
- Measurement of sample-loaded cavity (f_s and Q_s)
- Scalar measurement of transmission curve ($|S_{21}|$) is typically sufficient



$\Delta f, \Delta Q$

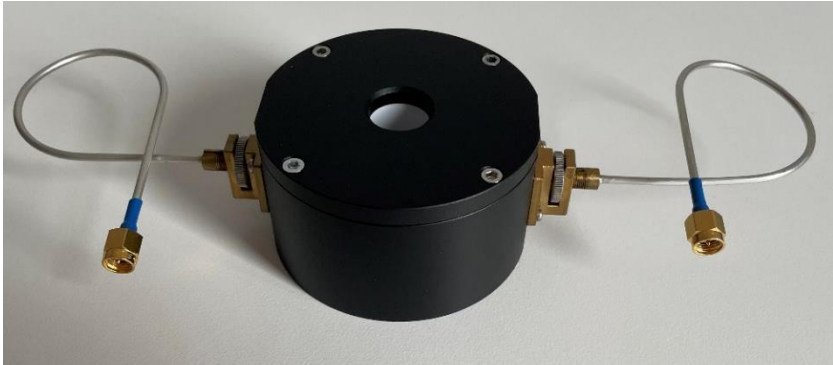
*Precise EM model
of the resonator*

*(embedded in the
dedicated software)*

$\epsilon_r, \tan \delta$

Measurement methods (3)

Dielectric resonator



Specification

Fluid diameter < 16 mm

$TE_{01\delta}$: $f = 2.45$ GHz ($Q = 29,400$)

$TE_{02\delta}$: $f = 5.16$ GHz ($Q = 27,200$)

Cavity resonator

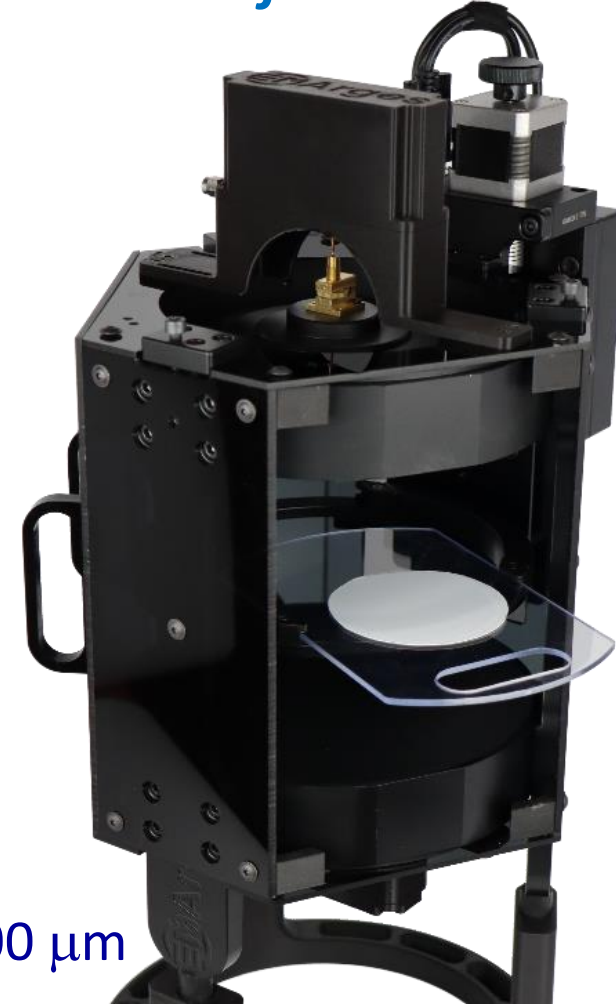


Specification

Fluid diameter < 3 mm

TE_{011} : $f = 23.8$ GHz ($Q = 14,200$)

Fabry-Perot open resonator with a dedicated fluid container



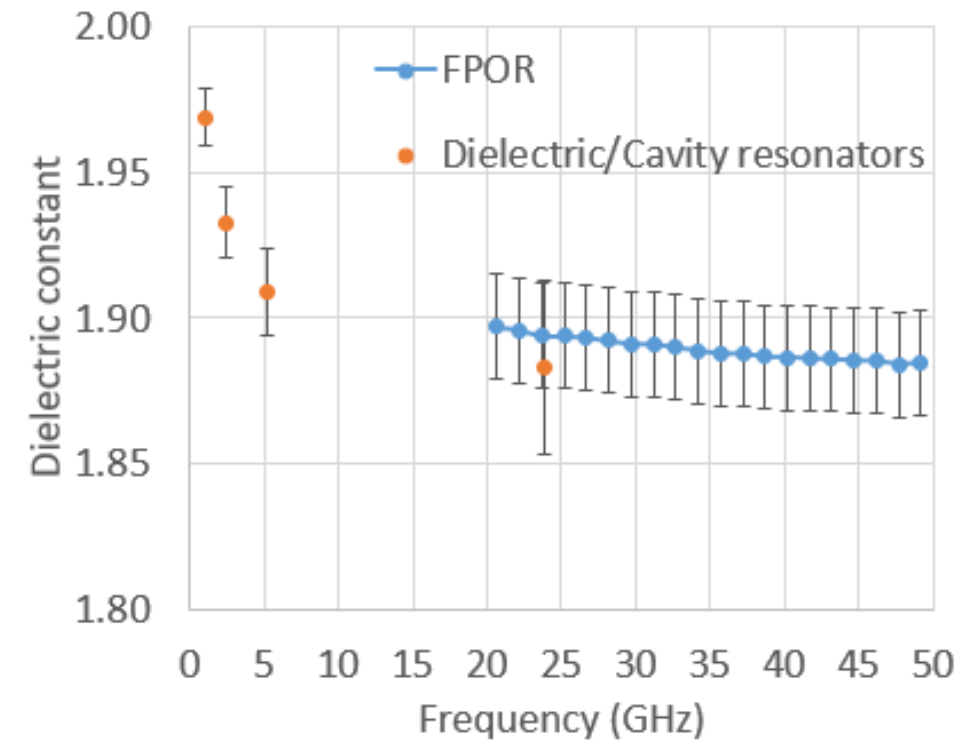
Specification

Fluid thickness: 100-400 μ m

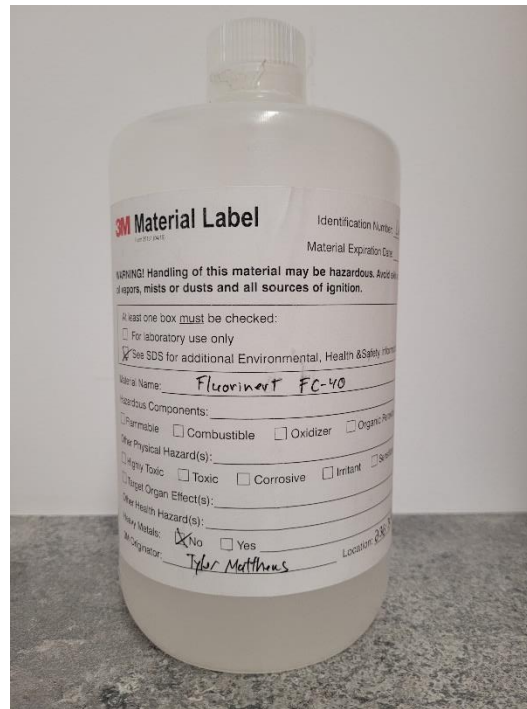
Frequency: 15-50 GHz

Electronic coolants

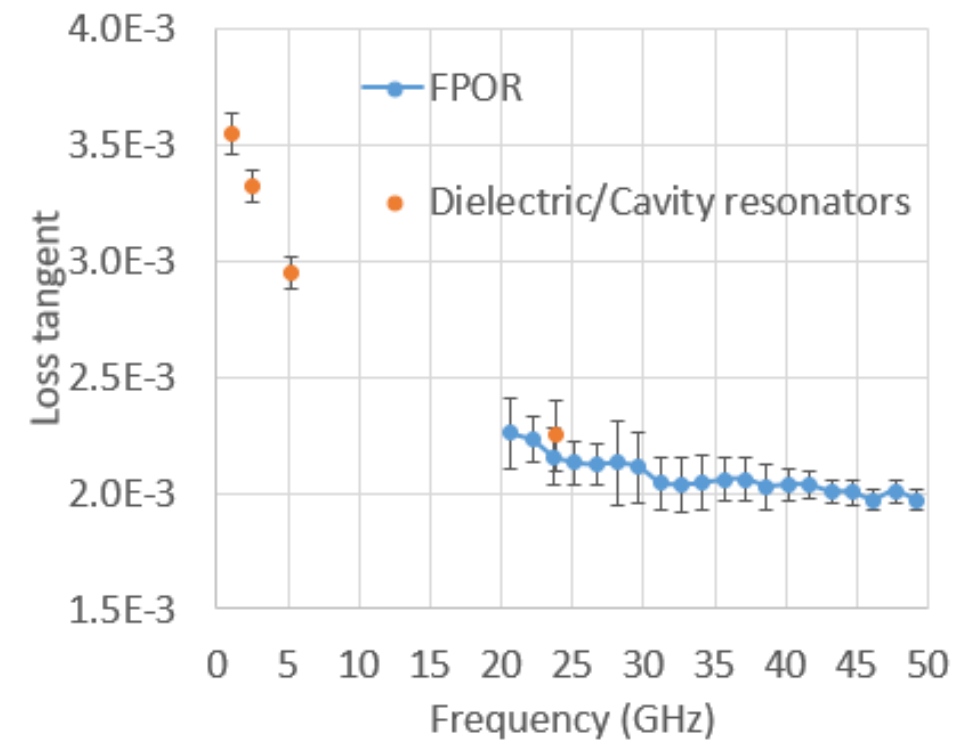
Low-loss liquids typically exhibit **dispersive properties** at microwaves
(Debye-like relaxation)



Dielectric constant

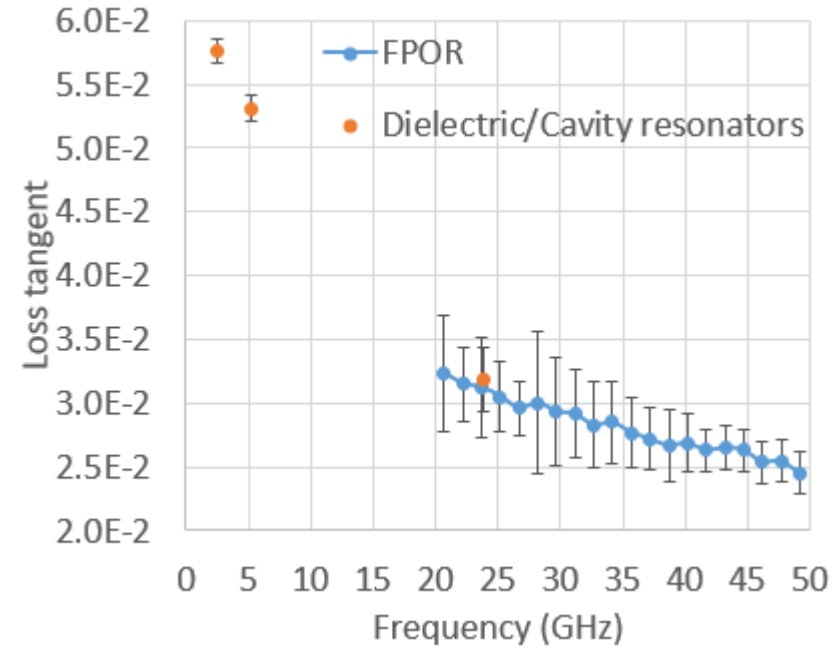
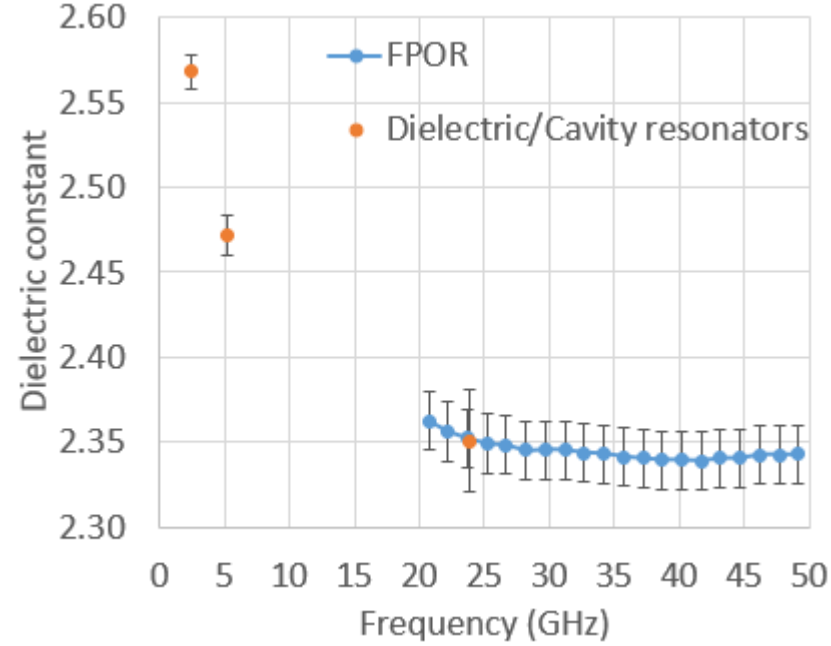


Fluorinert
(3M FC-40)

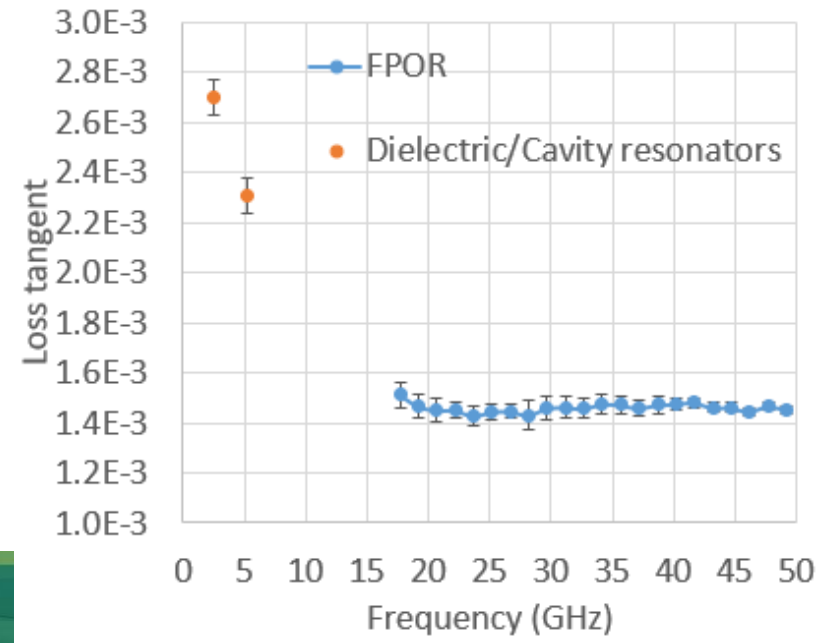
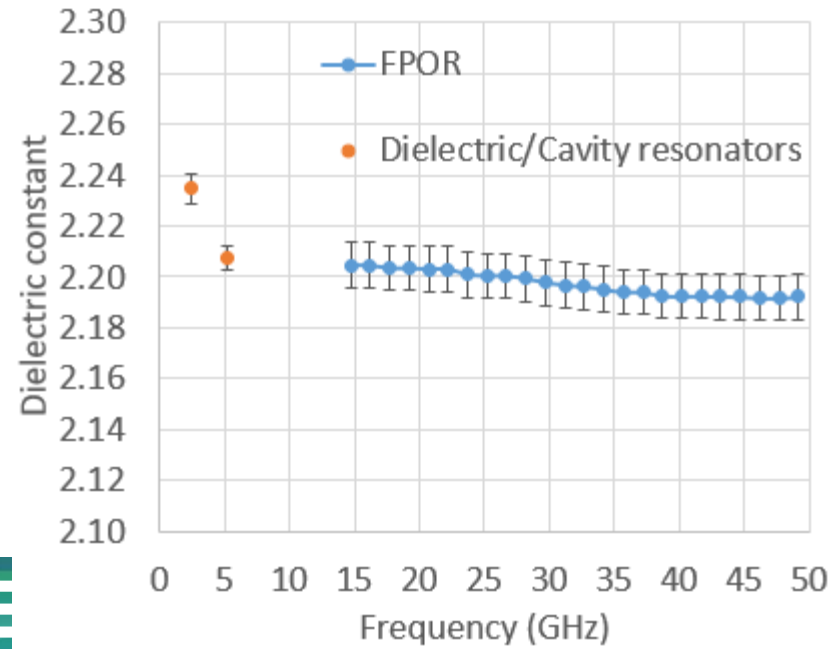


Loss tangent

Oils



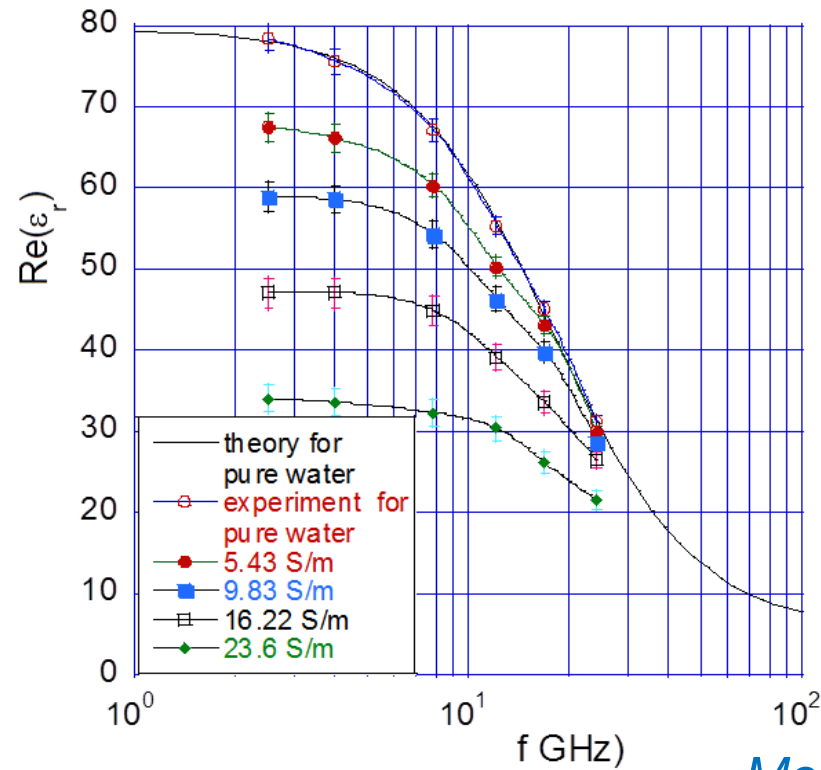
Canola oil



Engine oil

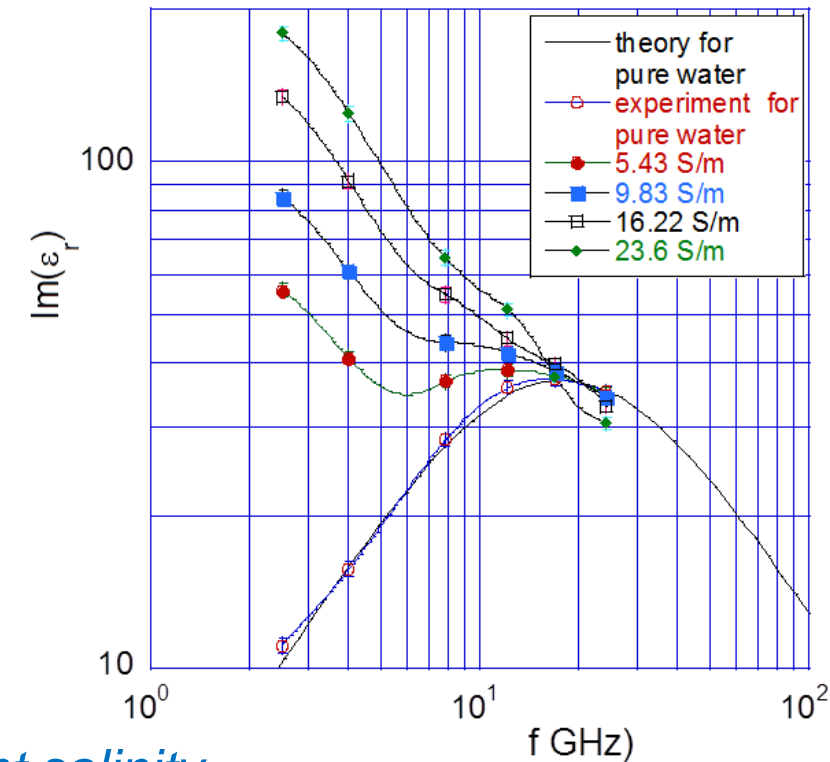


TE_{0mn} cylindrical modes provides superior accuracy in the characterization of lossy liquids, like saline water.



$$\varepsilon(\omega) = \varepsilon_{\infty} + \frac{[\varepsilon_s - \varepsilon_{\infty}]}{(1 + j\omega\tau)} - j \frac{\sigma}{\omega\varepsilon_0}$$

ε_s low-frequency limit
 ε_{∞} high-frequency limit
 τ relaxation time
 σ ionic conductivity



*Measurements of saline water for different salinity,
 at 2.5 GHz, 4 GHz, 7.86 GHz, 12.2 GHz, 16.9 GHz, 24.3 GHz*

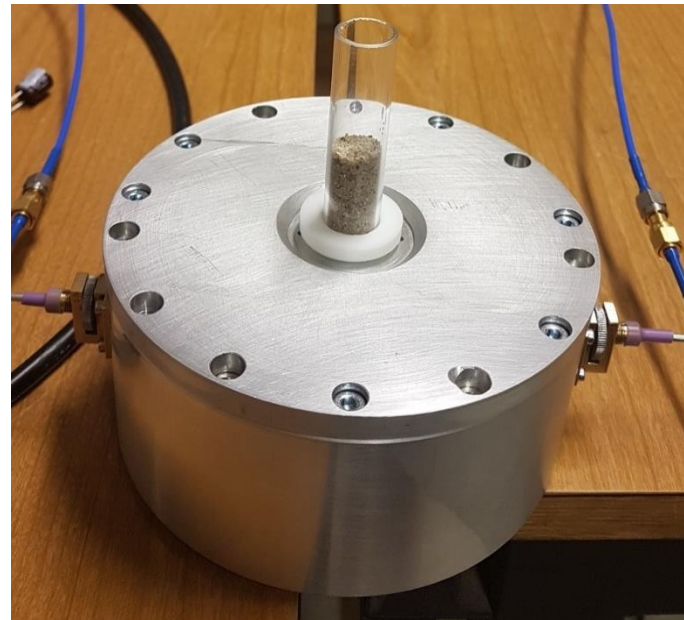
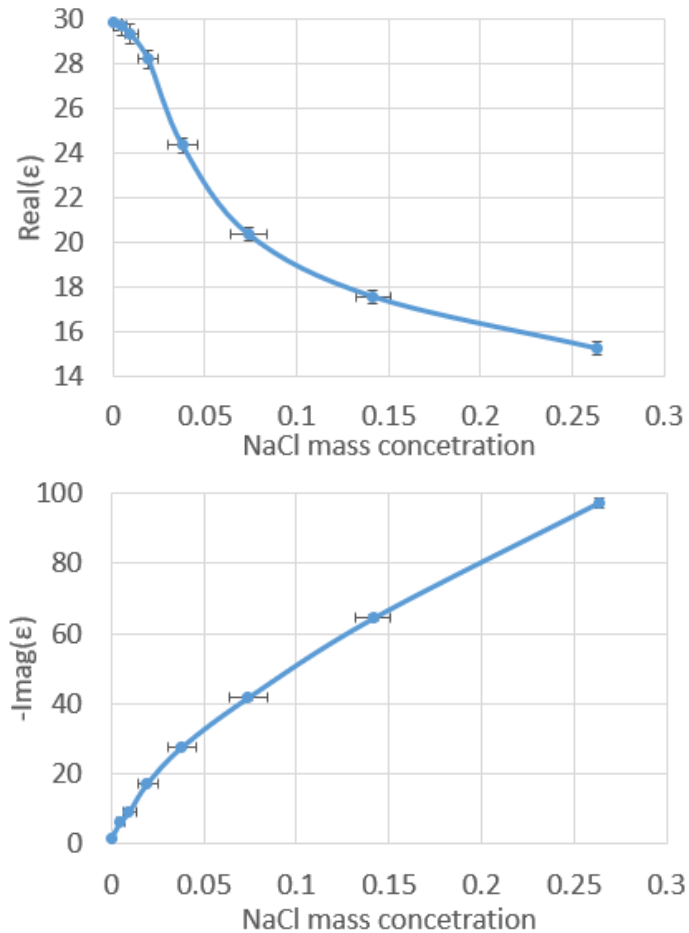
* J. Krupka, Measurements of the complex permittivity of highly concentrated aqueous NaCl solutions and ferrofluid employing microwave cylindrical cavities, Meas. Sci. Technol. 26 (2015).

Sand with saline water

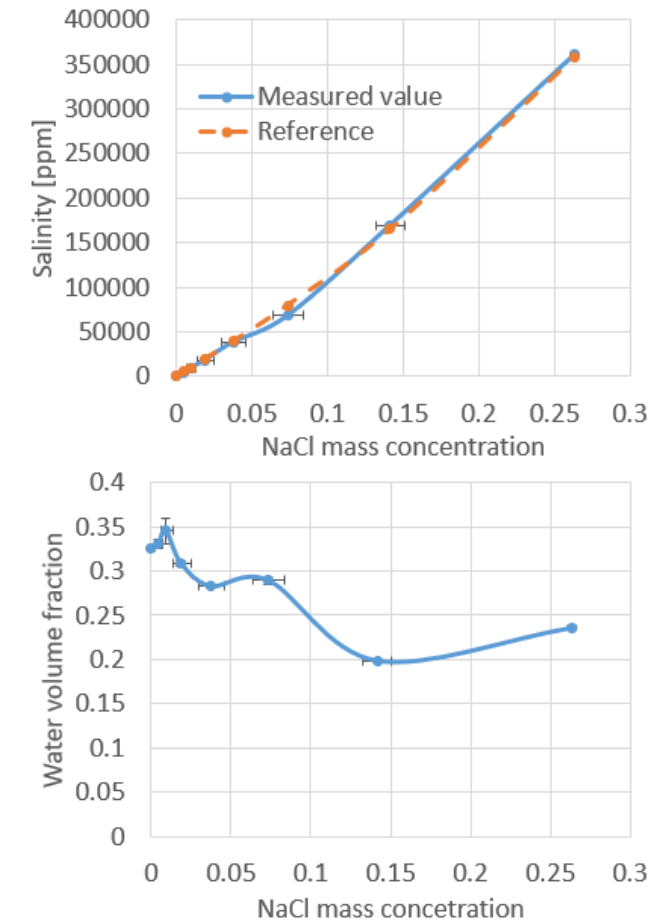
Intrinsic properties of mixture components can be evaluated

(e.g. using Maxwell-Garnett model)

$T = 22\text{ }^{\circ}\text{C}$



Dielectric resonator
(1.04 GHz)



Temperature measurements (1)

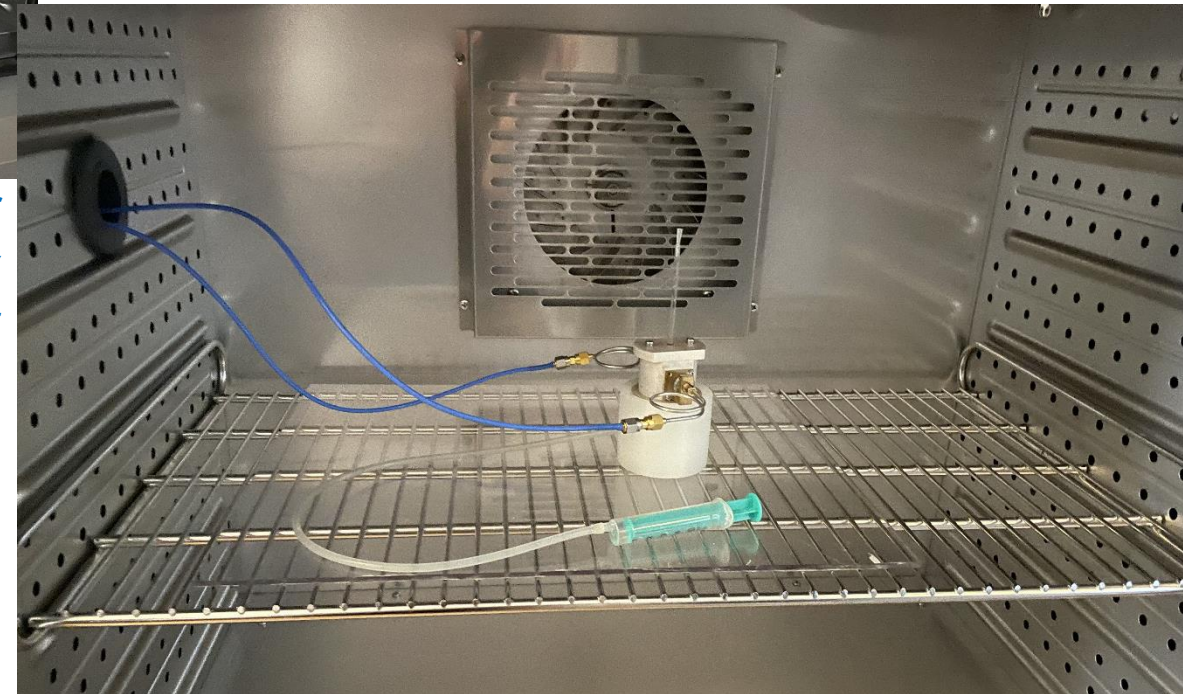
Dielectric characterization versus temperature



*PC with
control app*

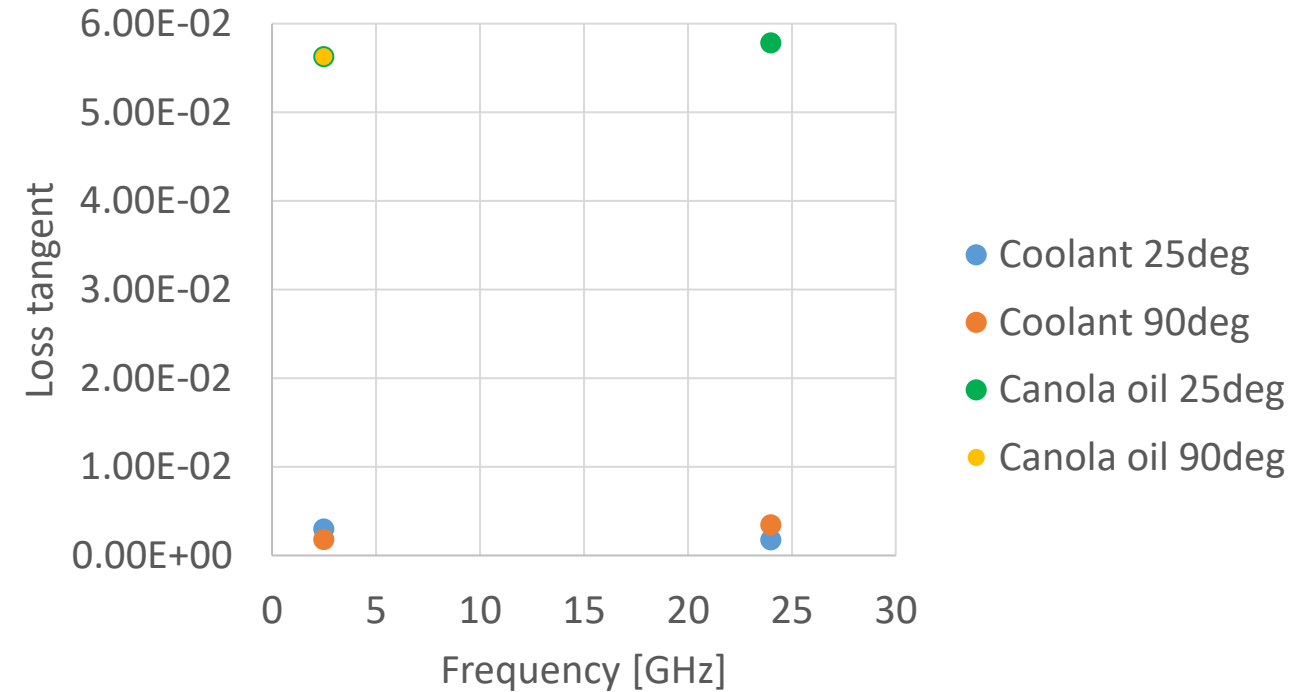
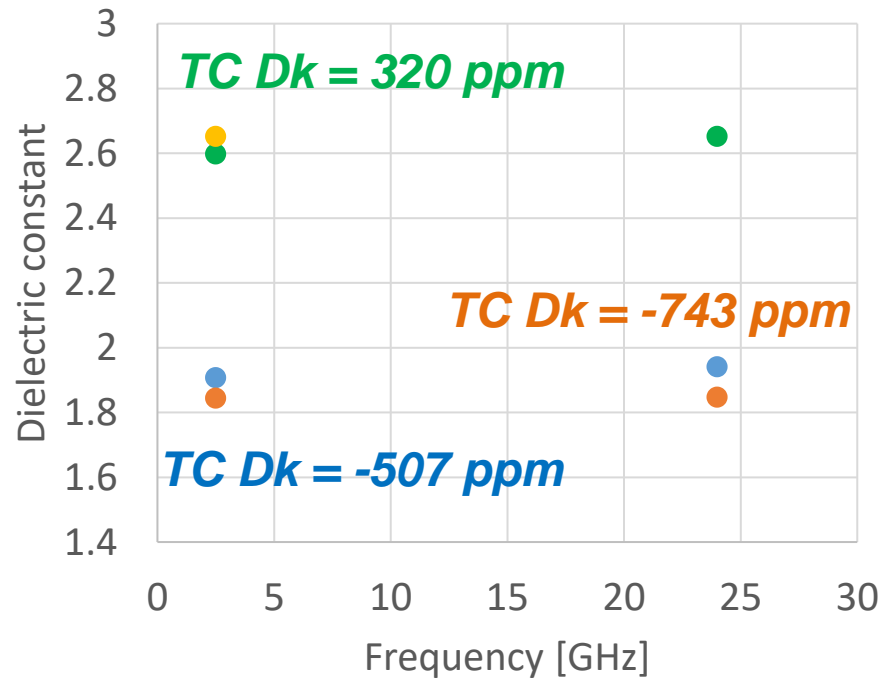
VNA

*Climatic chamber
with cavity
resonator @24GHz*



Temperature measurements (2)

Dielectric characterization versus
temperature coolant liquid and canola oil



Uncertainty of Dk due to variation of diameter of quartz tube
@2.5 GHz – 0.1%
@24GHz – 0.7%

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