Contactless device for 2D imaging and precise characterisation of electrical parameters of anode materials for battery cells

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Overview

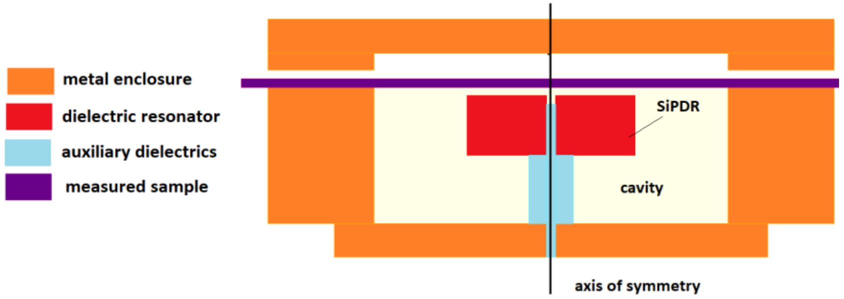
- Motivation
- 2D iSiPDR scanner for materials testing
- Measurement results
- Summary

Motivation

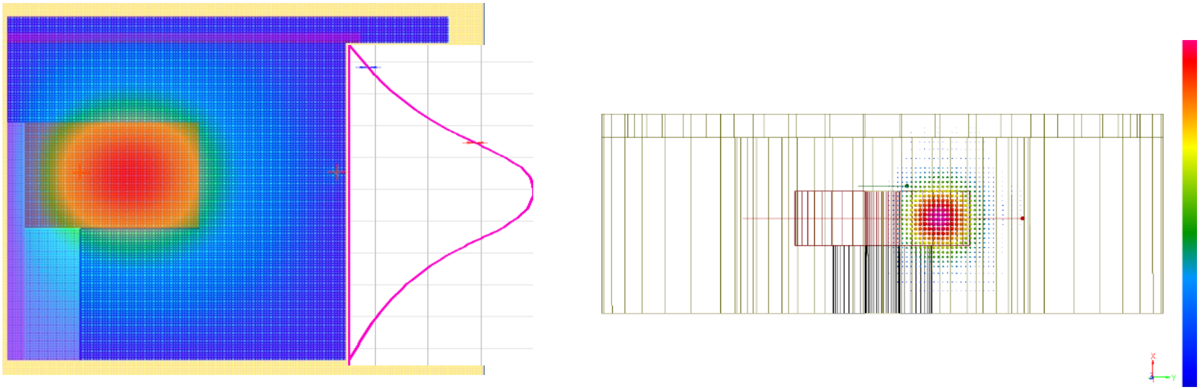
- Development of new materials for energy storage systems e.g. conducting composites
- New materials may significantly vary across its surface:
  - thin layer materials obtained through deposition
  - parameters' dependence on e.g. thickness non-uniformities or inhomogeneity of conductive inclusions dispersion.
- A need for monitoring parameters' variation over a material surface
  - important for battery anodes → electrical parameters directly influence efficiency of the battery cell,
  - quality testing for pre-manufacturing stage,
  - intermediate life-cycle testing → relating anode parameters to battery state of health (SOH),
  - investigating influence of solid electrolyte interphase (SEI) layer on overall anode quality,
  - post-usage testing for anode aging evaluation.
- Contactless device for 2D imaging of low resistivity and conductive materials

2D iSiPDR scanner for materials testing - basics

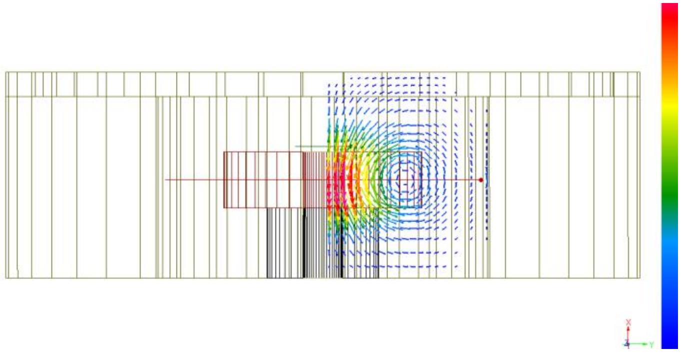
- Single-Post Dielectric Resonator – acknowledged material characterisation method
- sample between the single post dielectric and the ground plane
- weak E-field in sample plane (tangential E-field is zero at ground plane, increasing linearly towards sample plane)
- measurement of very lossy samples possible
- measurement sensitive to sample position
- measures resistivity or sheet resistance



Electric field distribution

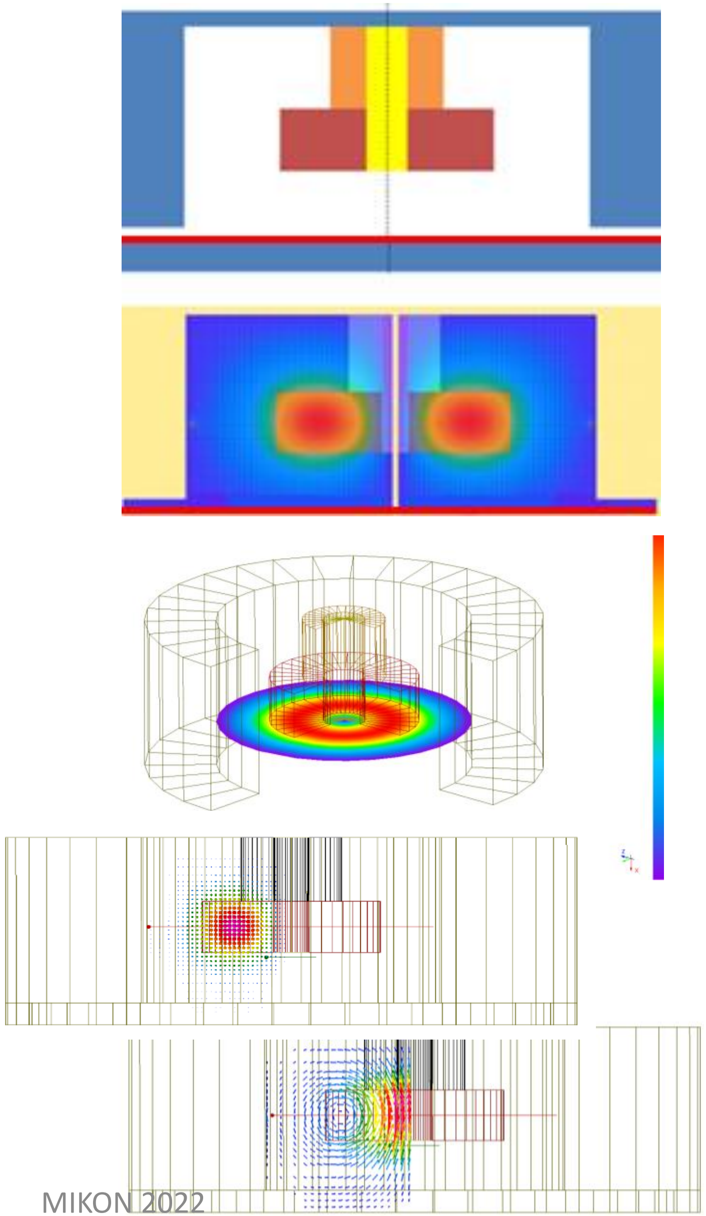


Magnetic field distribution

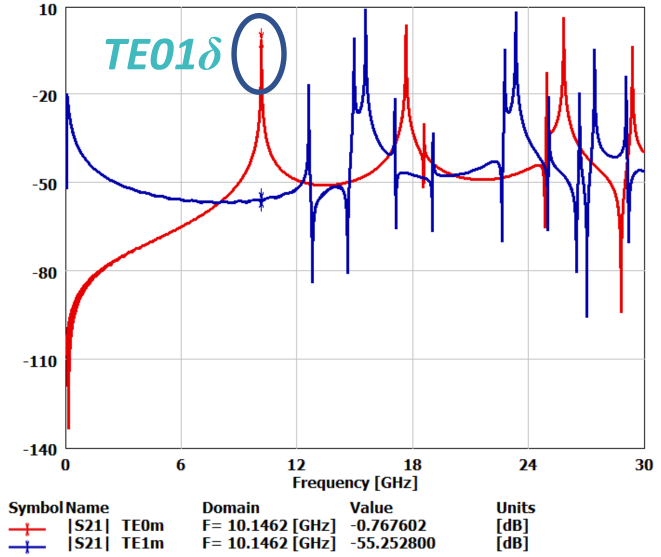


2D iSiPDR scanner for materials testing - design

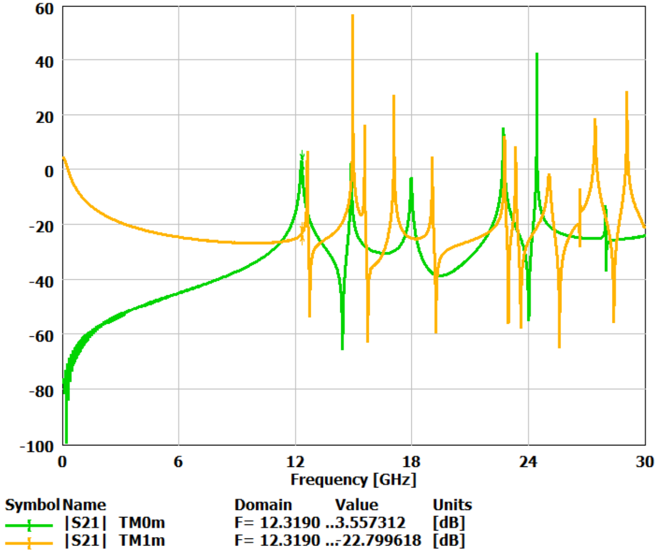
- Inverted SiPDR configuration
- 10 GHz chosen to improve raw spatial resolution
- Design with rigorous EM modelling
- Full-wave QuickWave BOR software
- Economies in computer effort by 10^3 or more
- Number of FDTD cells: 8 000
- RAM memory occupation: 1 MB
- Dedicated signal processing techniques applied
- Simulation time: 1 minute



TEnmδ modes: n=0, n=1



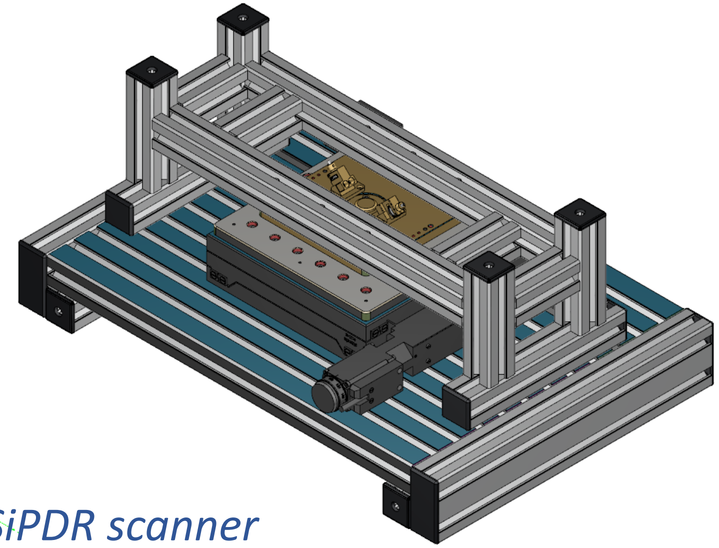
TMnmδ modes: n=0, n=1



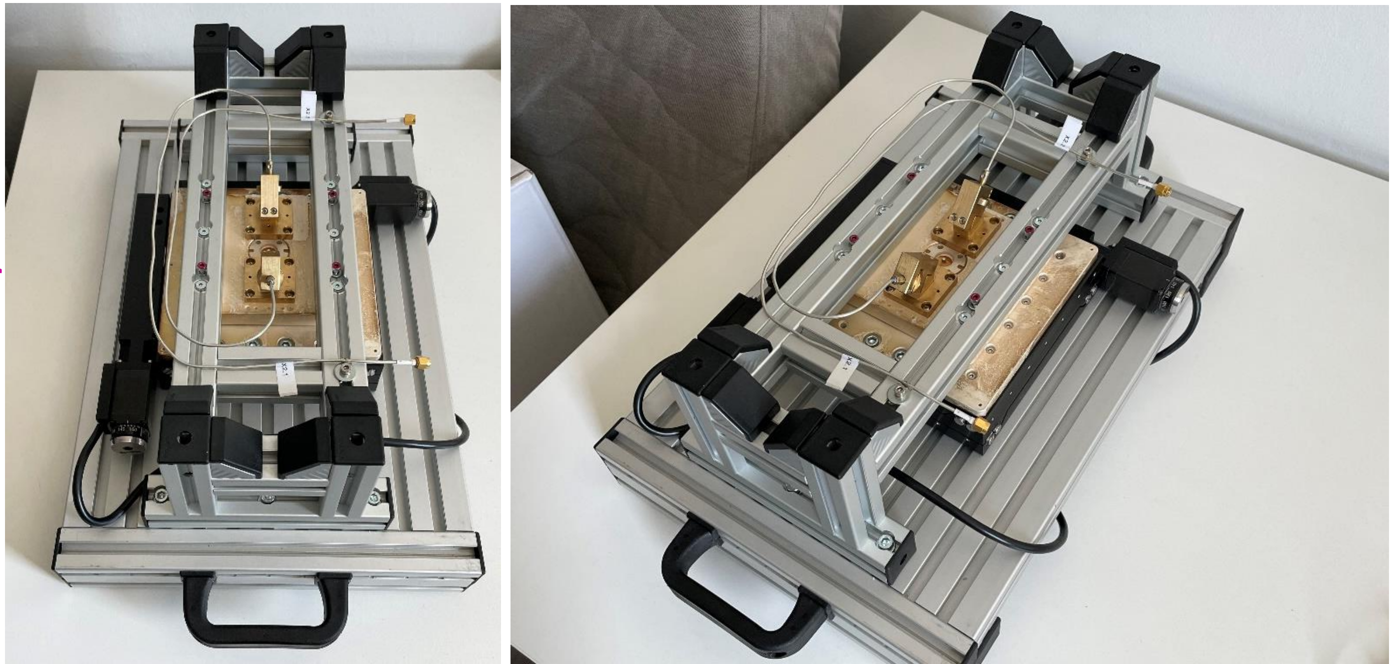
2D iSiPDR scanner for materials testing

- iSiPDR mounted over Standa 2D motorized translation stage
- Metal reference plate serving as a sample holder
- Sample holder size: 170 mm x 170 mm
- Scanning area: 100 mm x 100 mm
- Scanning step: 0.5 – 5 mm
- Admissible SUT thickness: max 1 mm
- 2D imaging a set of point-wise measurements
- In each point: measurement of f_{res} and *Q-factor*
- ρ or R_s extracted based on f_{res} and *Q-factor* of empty and sample-loaded device
- Extraction using LUTs

Mechanical design of 10GHz iSiPDR scanner



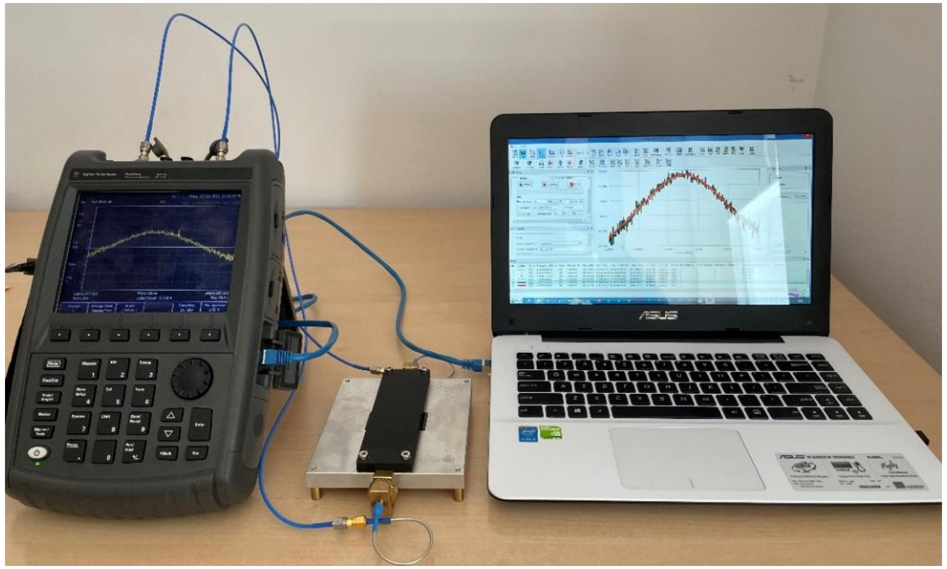
10GHz iSiPDR scanner



Measurement results - validation

- New 2D iSiPDR scanner validated for point-wise measurements.
- Validation against commercial 5 GHz SiPDR device.
- Two low-resistivity reference silicon samples (Siegert Wafers).
- Centre samples' area was investigated.
- Measurements with Keysight handheld FieldFox VNA.
- Good agreement between iSiPDR scanner and 5GHz SiPDR have been obtained.

Measurement setup with 5GHz SiPDR device



Device validation results

Device	Resistivity [Ω cm]	
	Sample 1	Sample 2
SiPDR 5GHz	0.003348	7.78
iSiPDR 10GHz	0.003416	7.48

Measurement results – material under test

- 2D iSiPDR 10 GHz scanner applied to 2D imaging of R_s of anode material for lithium-ion battery cells.

- Anode electrode made of polymer composite:
  - reinforced with graphene nano-platelets (GNPs)
  - GNPs: *avr thickness*= 15 nm, *diameter*≈ 5 μm, *aspect ratio*≈ 330
  - mixture of 92 wt. % of active material, 3 wt. % of conductive inclusions, and 5 wt. % of aqueous-based binder

- The substrate material:
  - 160 μm thick glass
  - lateral size: 24 x 50 mm.

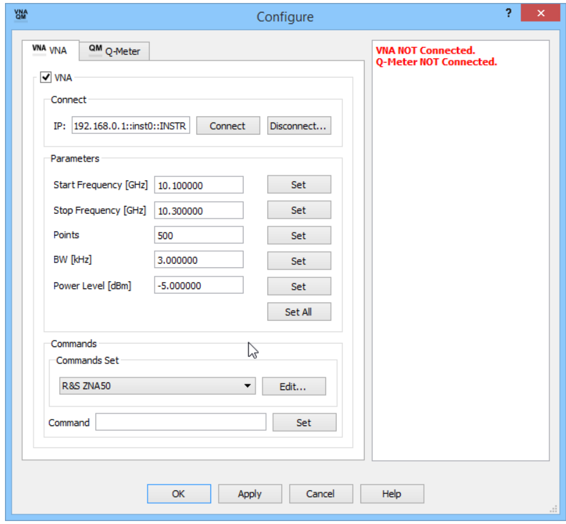
- Dried at a fixed temperature for about 2h.

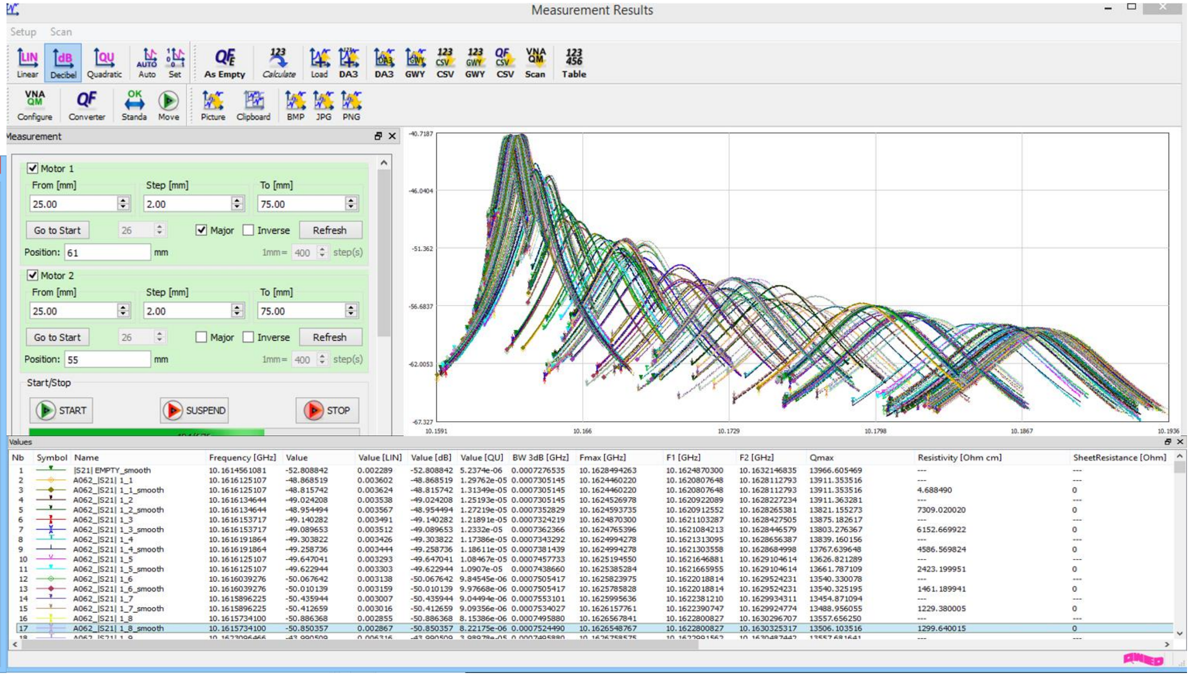
Substrate glass material and sample under test

Measurement results - 2D imaging setup

- Measurement setup: 10GHz iSiPDR scanner, VNA/Q-Meter, laptop with Scanner Unit Control Application
- Fully automated measurement procedure
  - VNA/Q-Meter configuration, communication & control
  - Configuration and control of the motors and XY-translation table
  - Built-in procedure for enhanced accuracy of Q-factor extraction
  - Material parameters extraction
  - Import/export options
  - Export of scan results to *.csv and industrial *.gwy formats

Measurement setup with 10GHz iSiPDR device



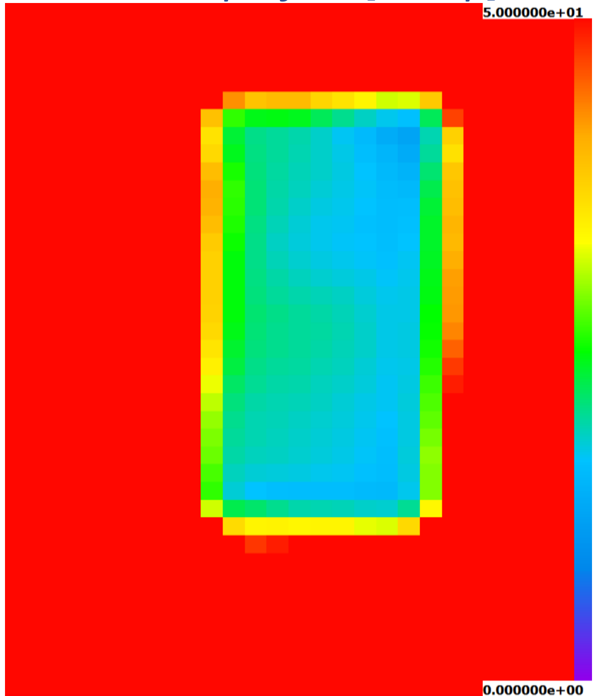


Measurement results - 2D imaging results

- Scanning area: 50 mm x 75 mm (25 mm margin around SUT)
- Uniform scanning step: 2 mm
- 1014 measurement points
- Avr thickness of the deposited graphene anode layer: 0.130 mm ± 0.02 mm
- Non-uniformities in R_s map due to sample thickness variation
- R_s extracted for average thickness value
- An absolute value of R_s can vary within uncertainty of ±15%
- Average R_s value of 19.3 Ω/sq. in exact agreement with a result of a point-wise measurement with 5GHz SiPDR device.

Measurement setup with 5GHz SiPDR device

2D map of Rs [Ω/sq.]



Summary

- An automated scanner device for 2D imaging of low-resistivity and conductive materials has been proposed.
- The scanner is based on inverted single-post dielectric resonator.
- The iSiPDR design has been conducted with the aid of full-wave electromagnetic simulations.
- The iSiPDR probe has been incorporated into automated mechanical design for 2D surface mapping.
- The iSiPDR device has been successfully validated on two reference samples.
- The 2D scanner setup has been applied to 2D imaging of graphene anode material dedicated for lithium-ion battery cells.
- 2D material imaging with iSiPDR scanner delivers both qualitative and quantitative measures of electric properties of investigated SUT.
- The scanning results are straightforward for samples with high thickness uniformity.
- Thickness inhomogeneities need to be accounted in evaluation of uncertainty of parameters' extraction.

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Thank you for attention!

Questions?

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