A Dielectric Waveguide Approach for Non-Destructive Extraction of the Complex Refractive Index

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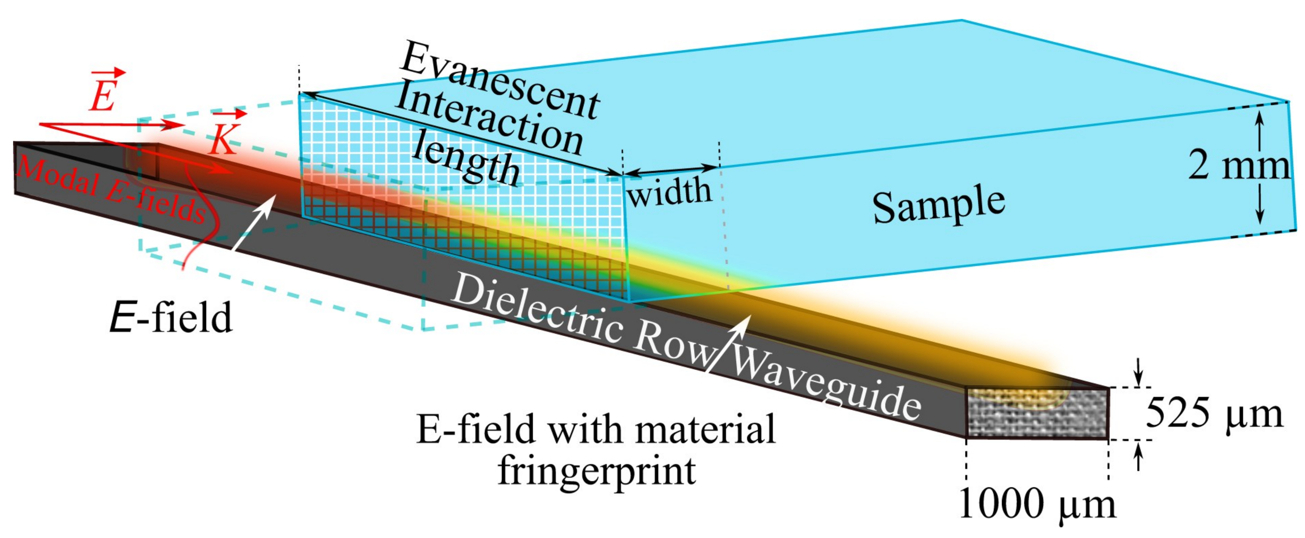
Abstract:

We demonstrate a dielectric rod waveguide method for the determination of the **complex refractive index** of materials for the mm-wave range. This work presents an Evanescent field interaction for determining absorption loss, real refractive index, and extinction coefficient for polymer samples.

Motivation:

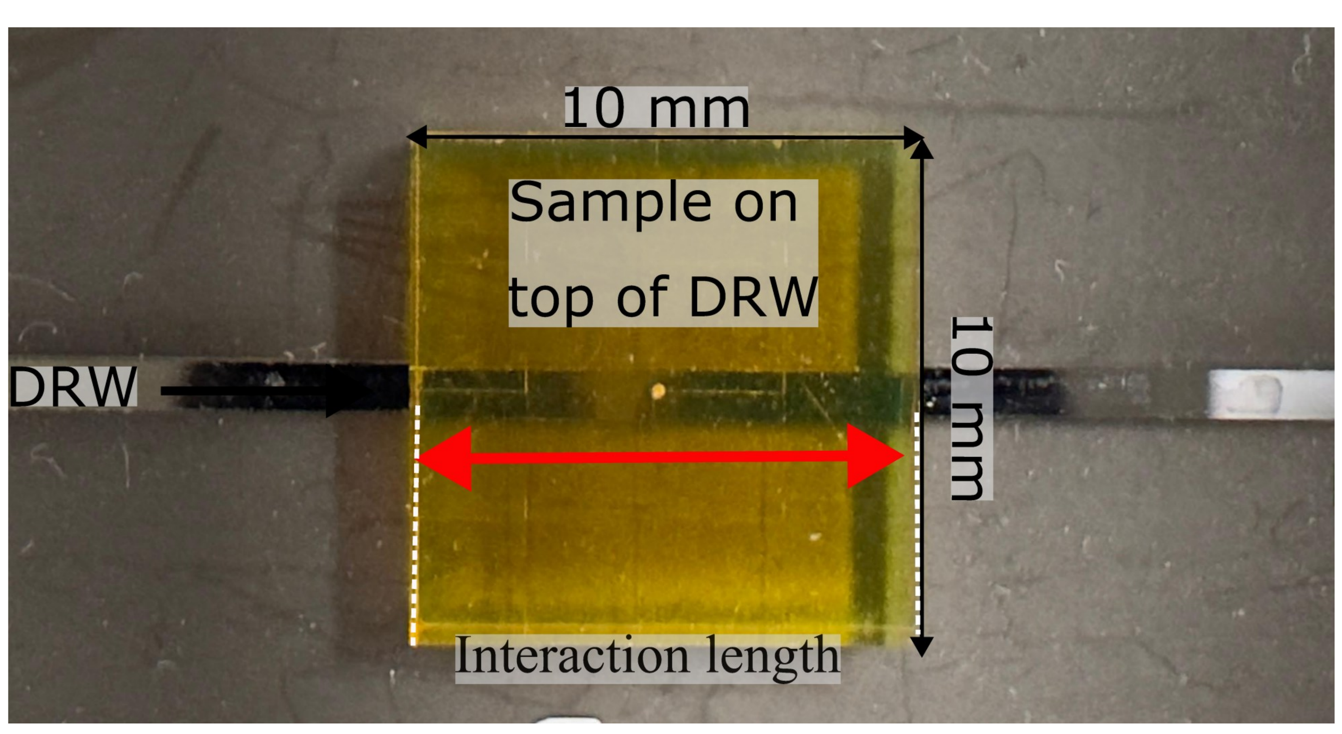
- Key applications for frequencies in the mm-wave & THz ranges: 5G, imaging, security [1].
- Critical need to characterize materials on those ranges [2].
- Drawbacks of traditional methods: Issues with thin & low loss materials, and dimensional precision demands [3],[4].
- Our Approach: Contactless sensing based on the evanescent fields in intrinsic silicon Dielectric Rod Waveguide (DRW). Overcomes limitations and enables measuring absorption, refractive index (n), and extinction coefficient (k) [5], [6].

Concept:



- A sample is positioned on top of a DRW (1mm width, 525µm thickness).
- Evanescent fields extend from DRW, interacting with the sample.
- Interaction alters wave magnitude (absorption) and phase velocity.
- Samples placed atop DRW for optimal coupling.

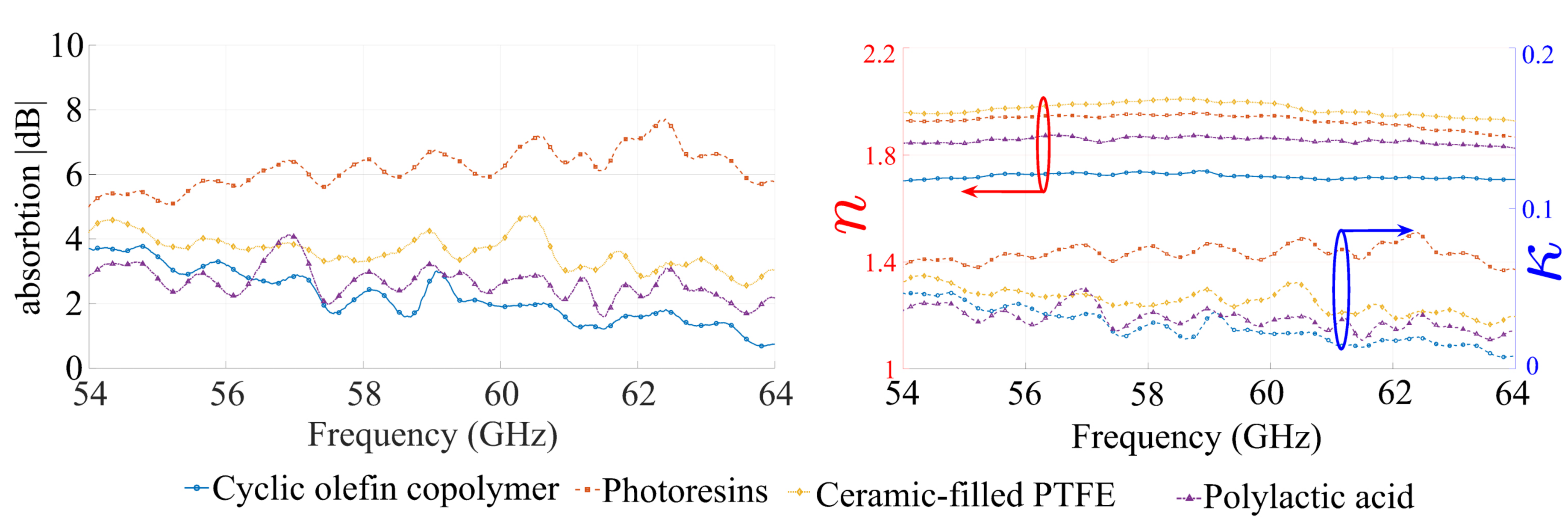
Demonstration:



- Absorption loss from transmission magnitude; n & k from phase velocity shifts.
- Materials: Cyclic Olefin Copolymer (COC), photoresins, ceramic-filled PTFE, Polylactic Acid (PLA).
- Frequency range: 54–64 GHz.

Results:

- **Distinct absorption loss trends :**
  - COC: Lowest (**<2 dB**).
  - Photoresins: Highest (**~8 dB** near 62 GHz).
  - Ceramic-filled PTFE & PLA: (**<5 dB**).



- **Refractive index (n) & extinction coefficient (k) :**
  - COC: n ~**1.7**, k <**0.02**.
  - Photoresins: n~**1.9**, k >**0.08** .
  - Ceramic-filled PTFE: n ~**2.1**, k~**0.05**.
  - PLA: n ~**1.83**, k ~**0.03.**

Conclusion

- DRW Evanescent field – material interaction response is viable for obtaining the complex refractive index.
- Useful to avoid environmental factors in measurements.

Further work

- Increase Evanescent field-material interaction bandwidth.
- Try liquid samples.

References

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