Optimized design for on-chip Fabry-Pérot resonators

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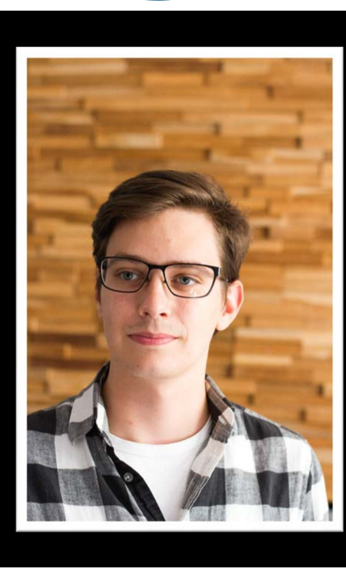

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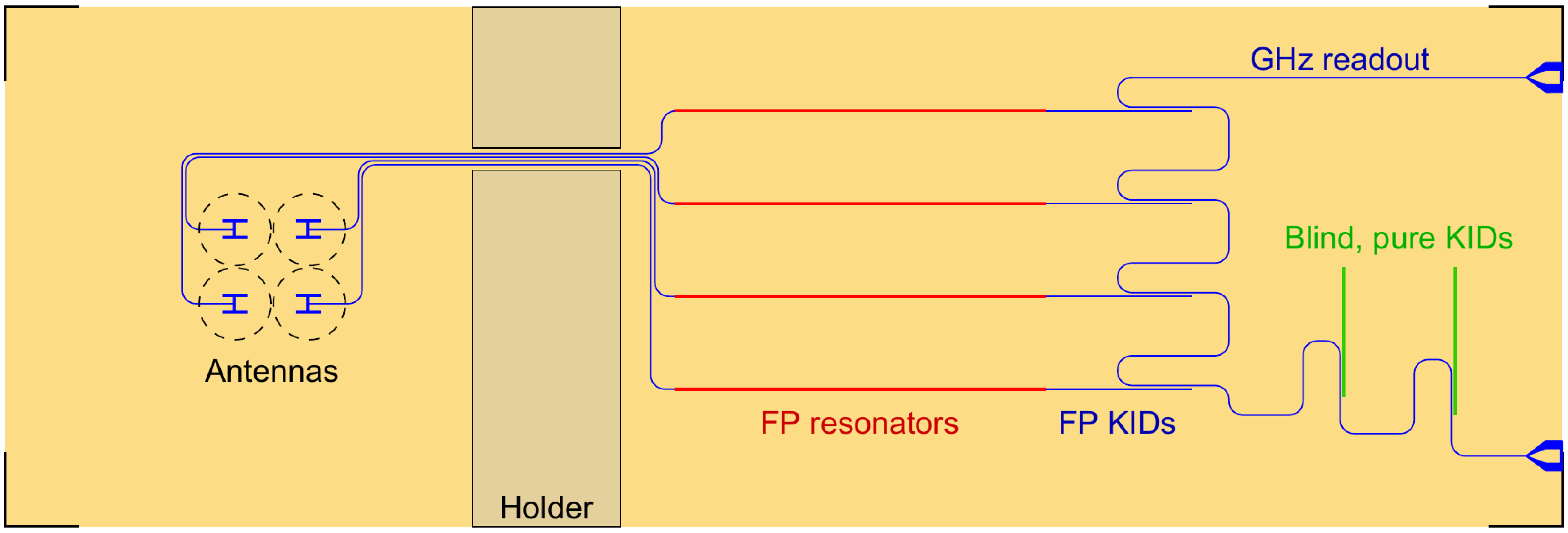


Motivation

- On-chip spectrometers, such as DESHIMA, require transmission lines with $tan\delta < 10^{-4} \rightarrow Q_i > 10^4$.
- Dielectric losses unknown under DESHIMA operating conditions.
- Design a lab-on-a-chip concept based on Fabry-Pérot resonators to measure the dielectric losses for:
  - Sub-K temperatures.
  - 300 GHz - 1.1 THz.
  - Q_i from 100 to 10^5.

DESHIMA:
Talk [160] Fr. 16:30 by A. Endo
Poster [236-259] by A. Pascual Laguna

Measuring the losses Q_i

Q_l: loaded quality factor → shape of the peak
Q_c: coupling Q-factor
Q_i: intrinsic loss Q-factor = $(tan\delta)^{-1}$

$$\frac{1}{Q_l} = \frac{1}{Q_c} + \frac{1}{Q_i}$$

- Problem: realised Q_c unknown due to fabrication uncertainties.

Measurement set-up:
Poster [181-147] by S. Hähnle

- Q_i limited approach:
  - Design resonator such that $Q_c \gg Q_i \rightarrow Q_l \approx Q_i$.
  - Limited frequency resolution of the source prohibits adequate sampling of the high Q_l FP peak → Not usable for high Q_i dielectrics.
- Full $|S_{21}|$ curve approach:
  - Relative peak height gives Q_c.
  - Not limited by frequency resolution of the source!
  - Limited by stray coupling → part of the curve is los

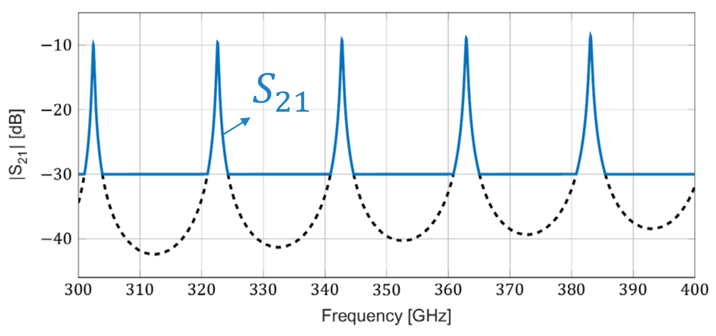


Fig: Stray coupling

Optimized FP Design

- Four independent resonators on a chip:
  - Each with different Q_c.
  - Probe the Q_l vs. Q_c curve.
  - Redundancy.
- Design resonators for full curve measurements:
  - Ensure entire $|S_{21}|$ curve lies above stray coupling limit.
  - The coupler sets $\min|S_{21}|$.
  - Desired Q_c can then be obtained by changing the length of the resonator → change mode number n.

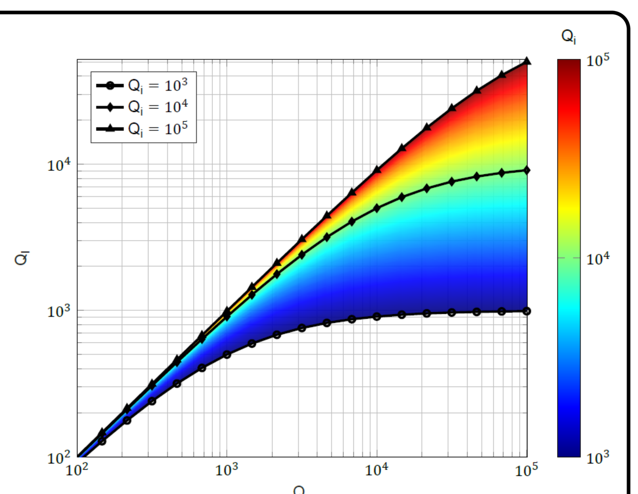


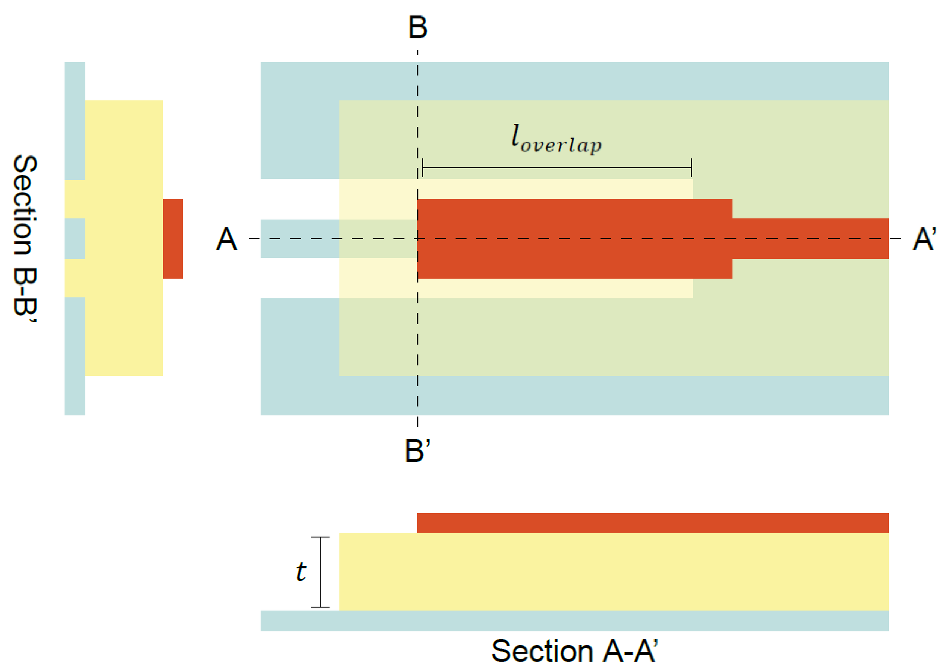
Fig: Q_l vs. Q_c curve

$$Q_c = \frac{n\pi}{|S_{21,coupler}|^2} \qquad n = \frac{f_n}{f_0} \qquad f_0 = \frac{c_0}{2 l_{resonator}\sqrt{\varepsilon_{r,eff}}}$$

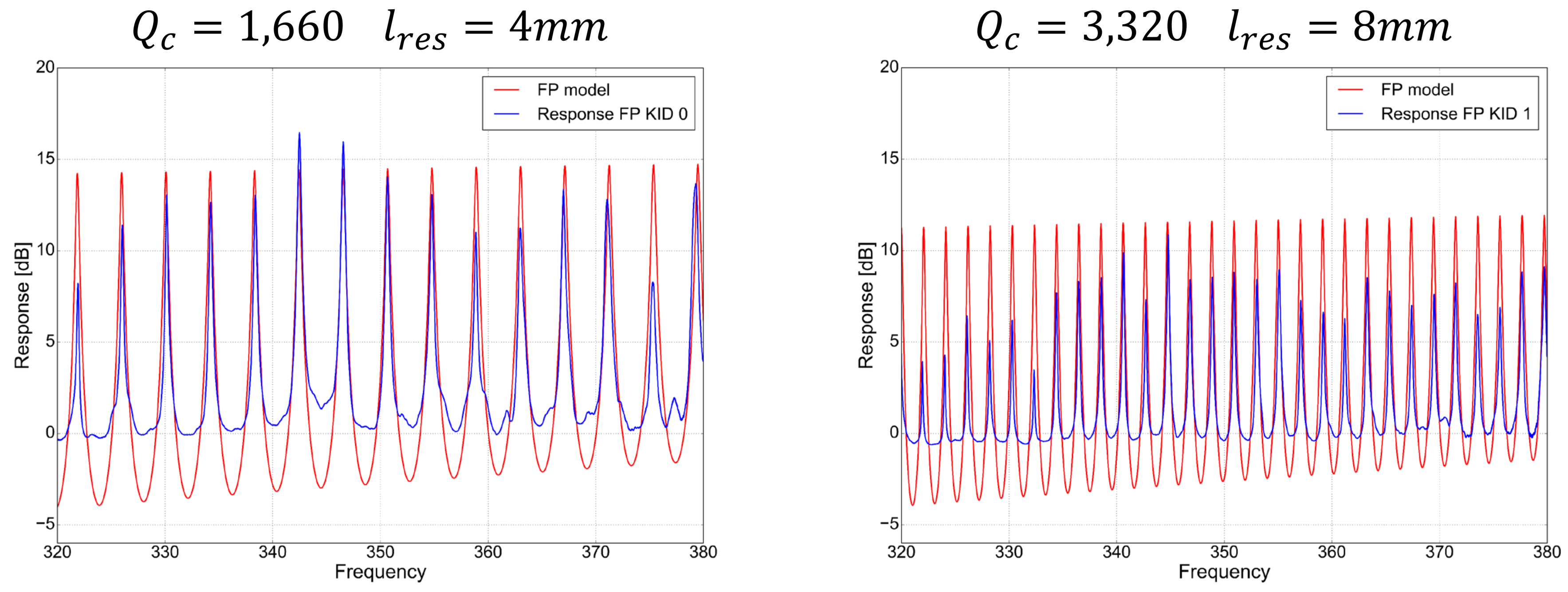
- **Advantages:**
  - Full curve approach enables measurement of Q_c!
  - Works for entire Q_i range of 100 to 10^5!
  - Not limited by frequency resolution of the source!
  - 4 resonators on a single chip!

CPW to microstrip couplers

- Couples microstrip resonator to CPW feed- and readout lines.
- $l_{overlap}$ sets $|S_{21,coupler}|$ and $\min|S_{21}|$ → full curve approach.
- Couples directly to the shorted MKID line.

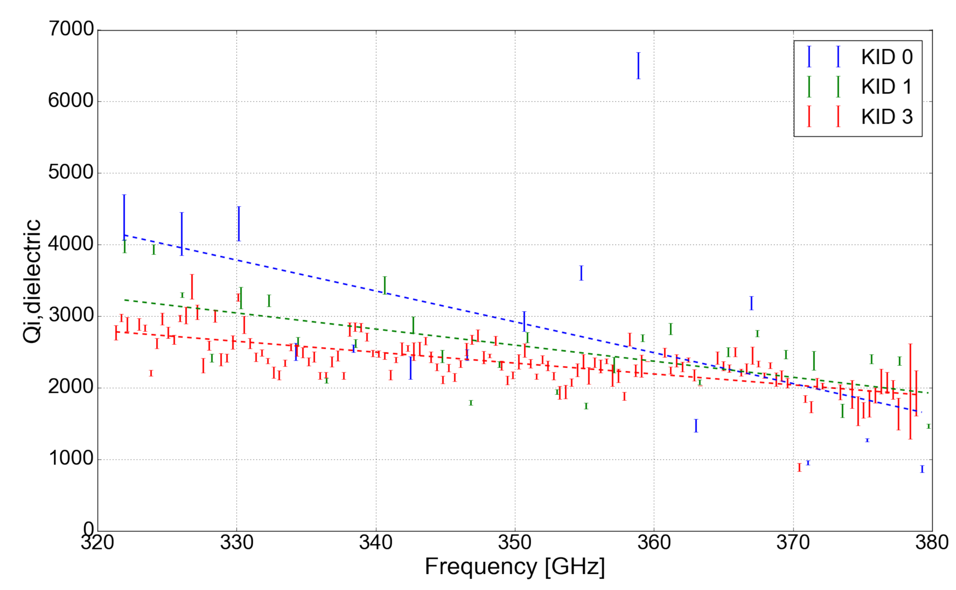


Modelled vs. Measured Response



Measured Q_i

- Able to measure losses of a microstrip at $300 - 400$ GHz!
  - $Q_i \sim 2000 - 3000$
  - $tan\delta \sim 0.33 \times 10^{-3} - 0.5 \times 10^{-3}$
- PECVD deposited a-Si.
- Sputter deposited NbTiN.



Conclusion and Outlook

- Measured losses of a superconducting microstrip at sub-K temperatures and **300 - 400 GHz!**
- Good match between modelled and measured FP response!
- Measured losses higher than expected.
  - Likely due to low NbTiN film quality → new fabrication run.
- Future work:
  - Additional structures for microwave ($4 - 8$ GHz) measurements.
  - Different dielectrics, deposited in-house → Study effect of deposition conditions.