Optical and RF Component Testing Platform

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SIST/GEM 5 Minutes 5 Slides
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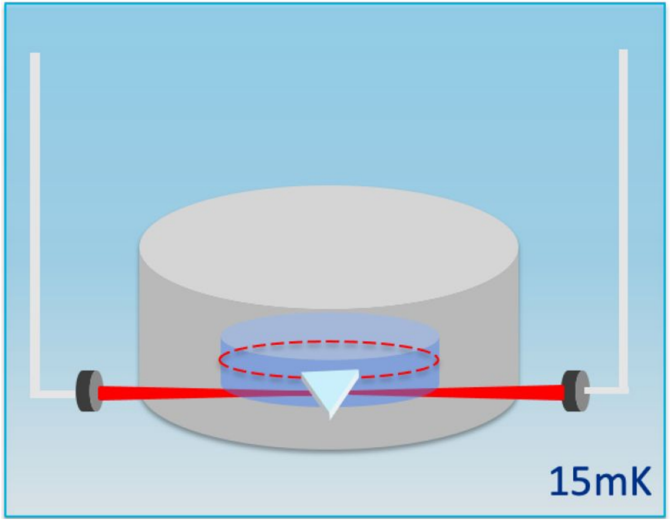
Background - Quantum Transduction

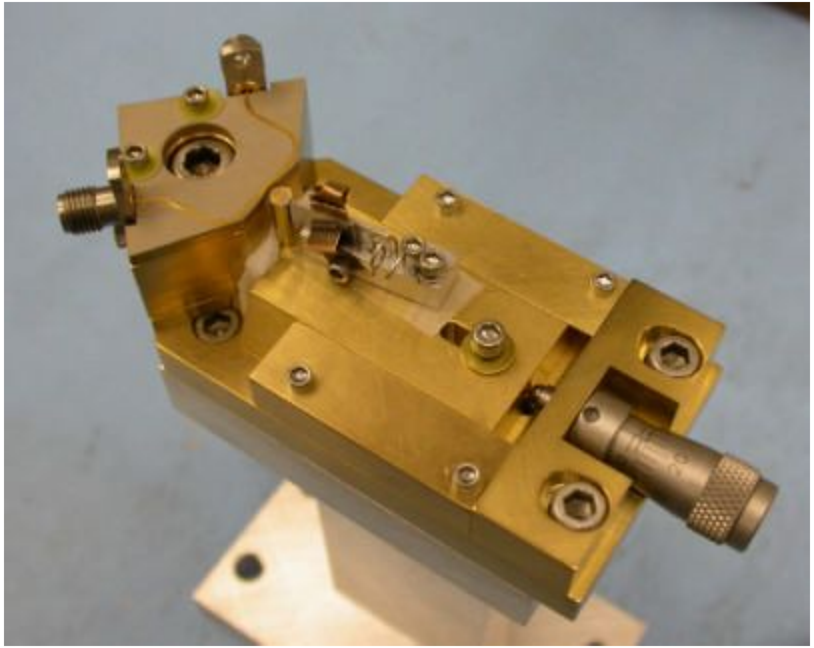


Block diagram of a microwave-optical bulk transduction device

- Superconducting qubits operate at cryogenic temperatures
- Quantum transducer needed to convert quantum signals between microwave and optical frequencies
- Would allow for a future distributed quantum computing network

Alam, M. S.,et al (2022). Quantum computing hardware for HEP algorithms and sensing. https://doi.org/10.48550/ARXIV.2204.08605

Variable Optical Resonator

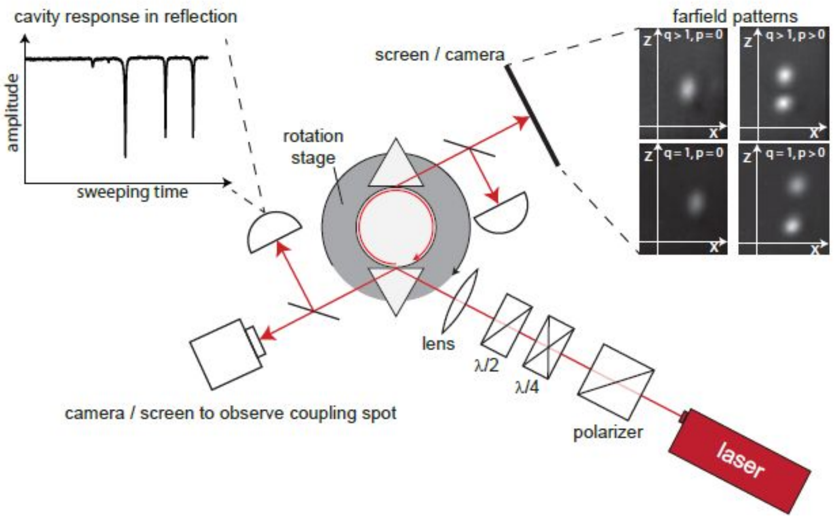


Wireless self-homodyne microdisk RF-photonic receiver with RF coupling tunability

M. Hossein-Zadeh and A. F. J. Levi, "Self-homodyne RF-optical microdisk receiver,",*CLEO 2004*

- Electro-optic quantum transducer conducts microwave-to-optical frequency conversion using a lithium niobate WGM resonator
- Optical coupling strength is tunable
- Testing optical coupling methods, resonator crystals and coupling prisms

Optical Coupling Motion Requirements

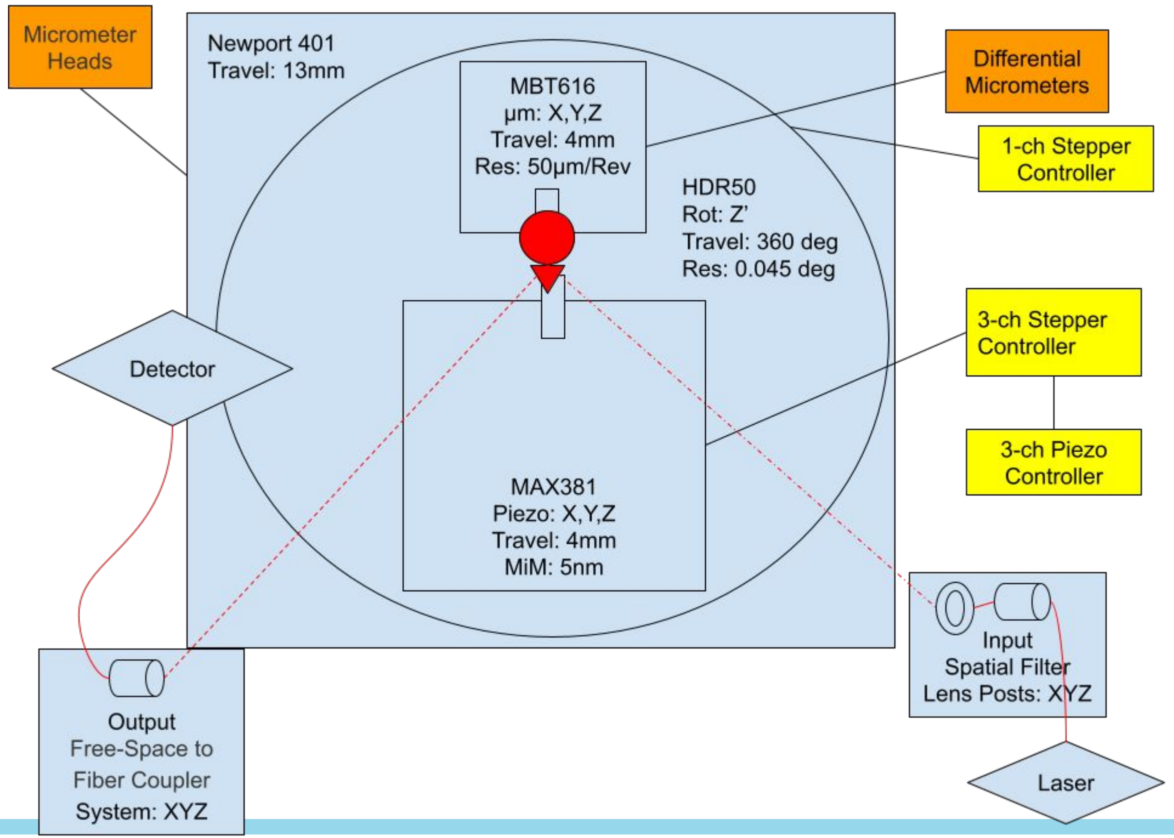


A typical setup for coupling to WGM resonators

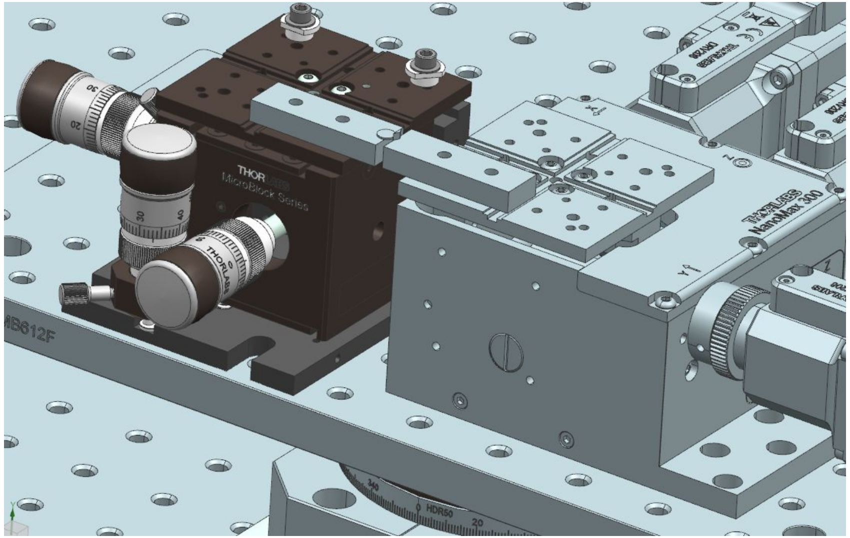
Sedlmeir, Florian. (2016). Crystalline Whispering Gallery Mode Resonators.

- Ambient Temperature
- Prism needs to be moved with nanometer precision
- Rotation
  - Combined setup of prism and resonator
  - **Or** Beamline Input/Output
- Closed-Loop Controls
- Budget 20K
- In Stock Availability (No lead time)

Optical Table Setup Diagram



Objectives



- Design and assemble optical and RF component testing platform for quantum transduction
- Conduct optical coupling procedure and characterize optical modes
- Potentially investigate deformations of resonator crystals caused by the piezoelectric effect and their effect on resonator coupling strength
- Potentially test RF components and coupling

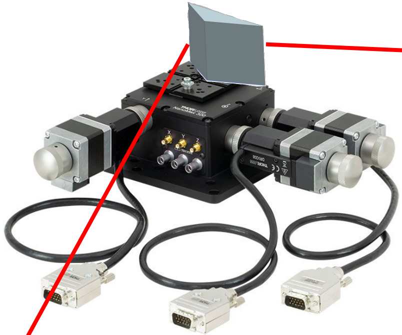
Thank you

Questions?

Extra Slides

Backup

Motion Stage Solutions



Prism - Piezo XYZ Stage

MBT616D

Crystal - Micrometer XYZ Stage

Resonator Setup - Stepper Motor Rotation Stage

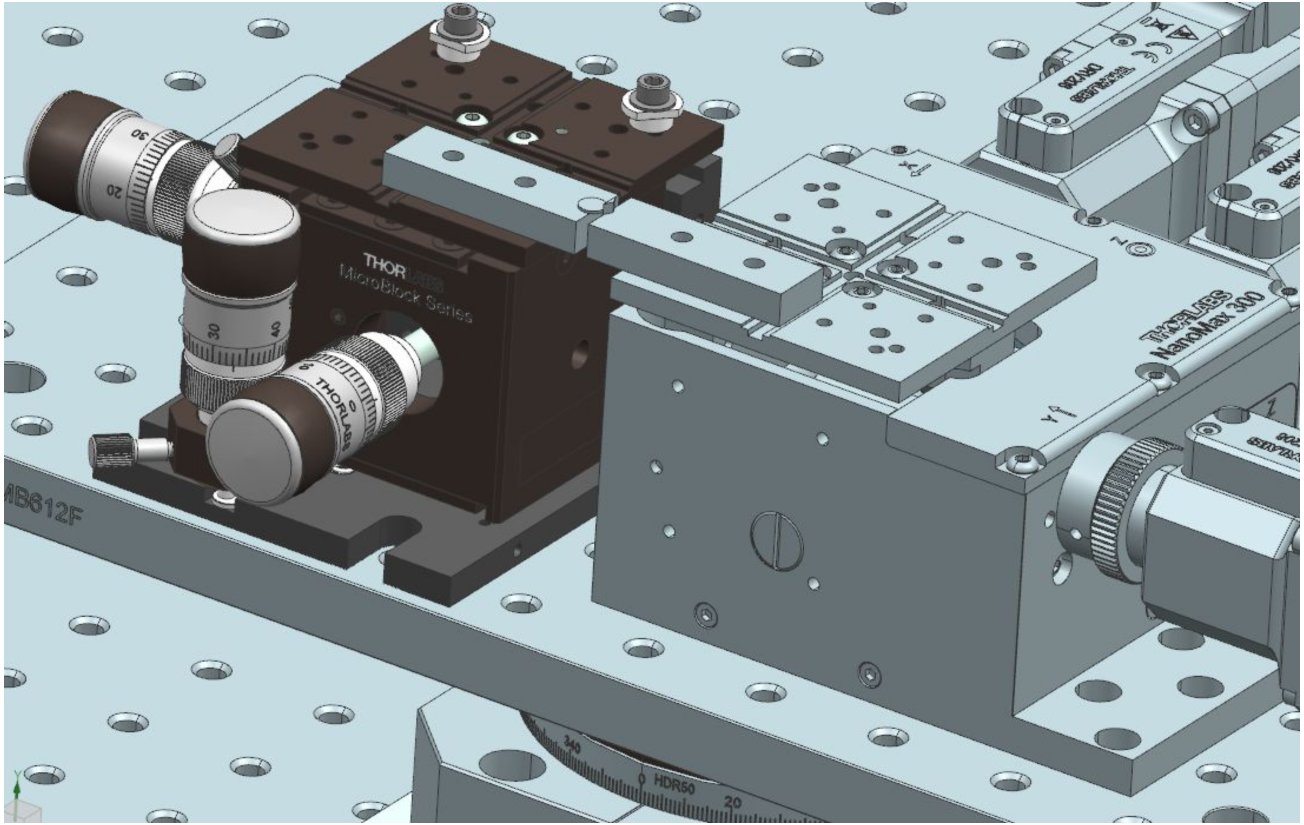
Input - Kinematic mounts on optical posts

Resonator Setup - Micrometer XY Stage

Output - Free-Space to Fiber Coupler

KT311

Preliminary CAD - Option 1



Option 1 Considerations

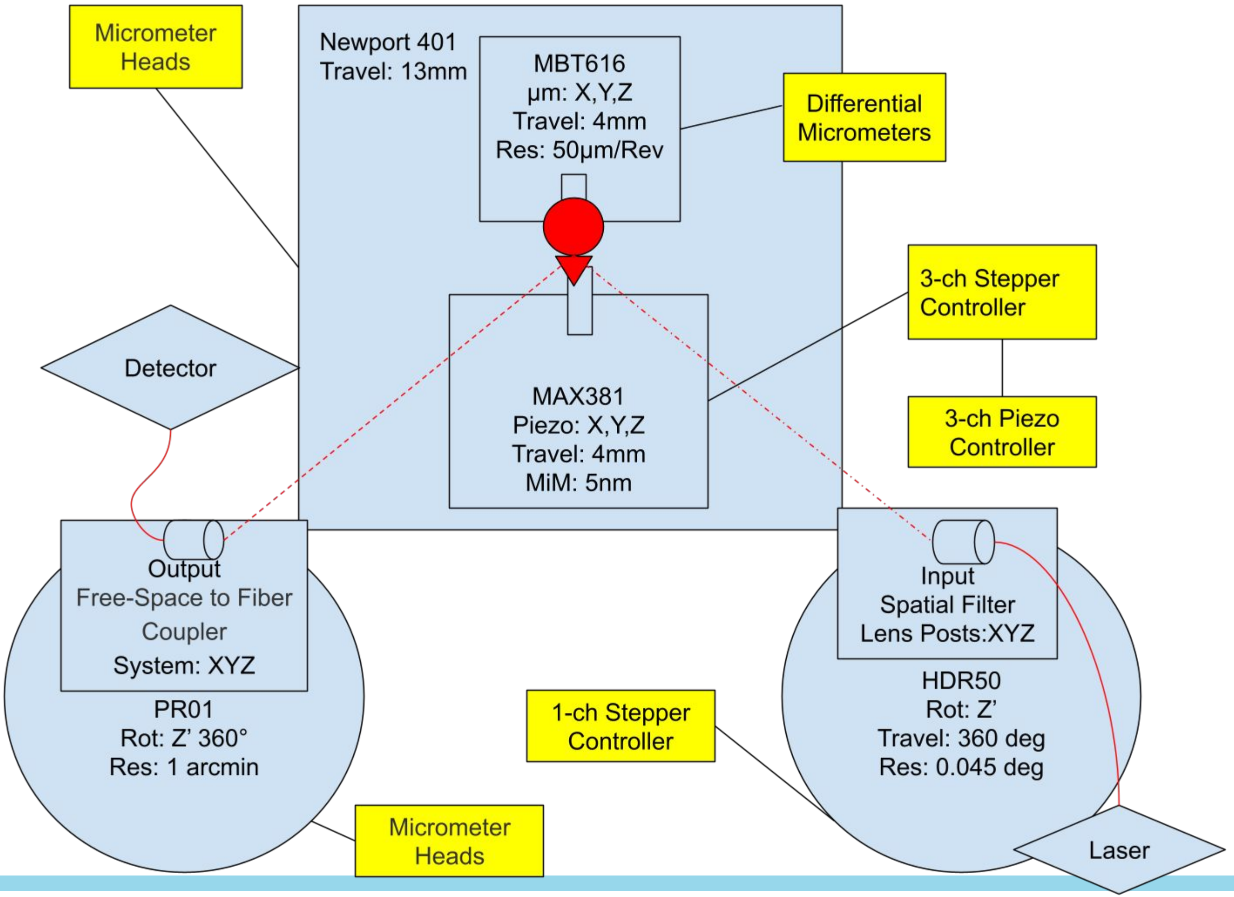
- Aluminum breadboard attached by steel set screws
- Small radius rotation platform, torque will cause small off-axis wobble
  - Potentially um scale wobble
  - Option 2 is a backup if wobble is too large
  - Beamline will be rotated instead of resonator setup
- Need to mount lens positioning systems on posts with rough z-axis tunability for beamline-resonator height match

BOM - Option 1

Component	Quantity	Unit Cost	Prt. #	Vendor	Description	Notes
3-Axis NanoMax Stage, Stepper Motor Drives, Closed-Loop Piezos, Metric	1	4140.54	MAX381	Thorlabs		2.8kg
3-Channel 150 V Benchtop Piezo Controller with USB	1	5144.21	BPC303	Thorlabs		Controller
Three-Channel Benchtop Stepper Motor Controller	1	3081.7	BSC203	Thorlabs		Controller
3-Axis MicroBlock Stage with Compact Differential Adjusters	1	1,214.54	MBT616D	Thorlabs		0.75kg
BSC201 One-Channel Benchtop Stepper Motor Controller	1	1530.55	BSC201	Thorlabs		Controller
MB612F - Aluminum Breadboard, 6" x 12" x 1/2", 1/4"-20 Taps	1	96.22	MB612F	Thorlabs		1.51kg
NR360SP8 - Adapter Plate for HDR50 Stage, SM1 Threaded, 30 mm Cage Compatible, 1/4"-20 and 8-32 Taps	1	54.65	NR360SP8	Thorlabs		0.18kg
Heavy-Duty Rotation Stage with SM2-Threaded Center Hole, Imperial	1	2914.92	HDR50	Thorlabs		1.5kg
Micrometer Head, High Resolution, 0.5 µm Sensitivity, 13 mm Travel	2	199	HR-13	Newport		
XY Linear Stage, 13 mm Travel, 1/4-20 Thread	1	773	401	Newport		
		19348.33				

Fermilab

Optical Table Setup Diagram - Option 2



Coupling Alignment Process

1. Change the coupling distance between the prism and the resonator till the contrast of the modes reaches its maximum (critical coupling)
2. Optimization of coupling contrast with the xyz stage
3. The coupling angle has to be increased slowly while repeating the first two steps until only few, fundamental modes remain. When increasing the coupling angle, the last mode which couples eciently before coupling disappears can be identified with a q=1 mode.
4. Now the desired mode should be chosen, usually that with best coupling and narrowest linewidth. Note that the optimal coupling parameters differ for different types of modes: higher order q modes require smaller coupling angles, while higher order p modes require non-zero angle with respect to the plane of the resonator.
5. Finally, if possible, the numeric aperture of the coupling lens can be changed for optimum contrast.

Sedlmeir, Florian. (2016). Crystalline Whispering Gallery Mode Resonators.