Toward Chip Integrated Ultra-Low-Noise Lasing Using a Microrod Resonator

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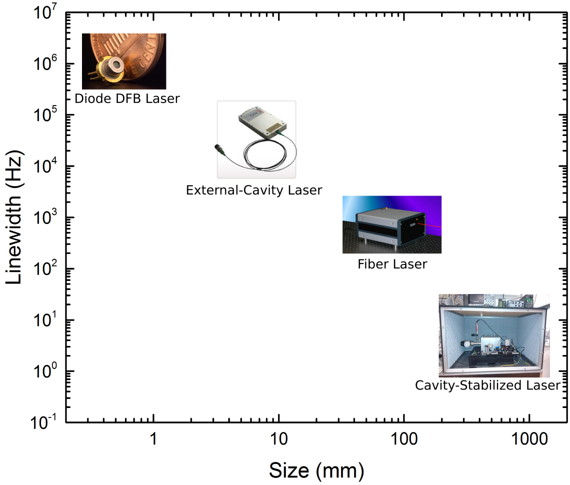
Current Laser Technology

Microrod Lasing

J. Becker

- **Background**
- Experiment
- Results
- Conclusions

As lasers increase in stability they increase in size.



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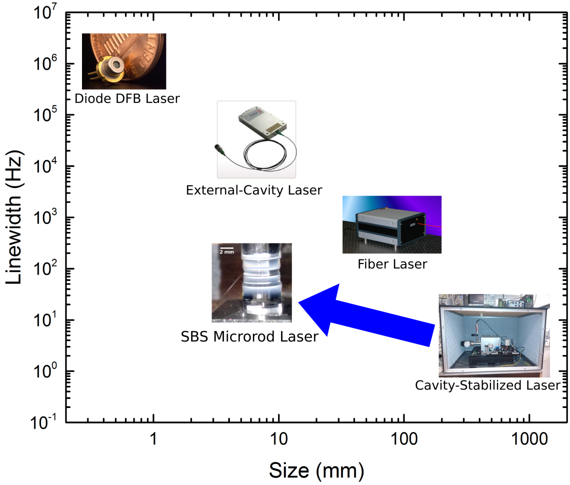
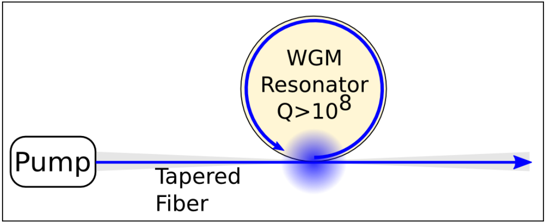
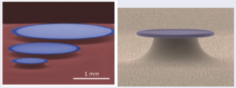


Whispering Gallery Mode Resonators

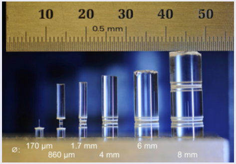


Silica Microdisk



H. Lee, Nature Photon, 2012

Silica Microrod

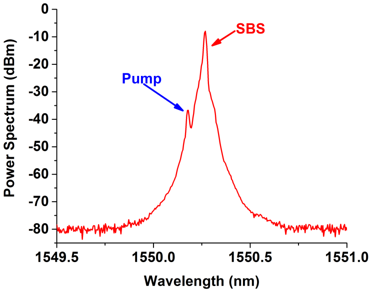


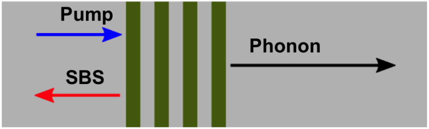
P. Del'Haye, APL, 2013

CaF_2 Resonator

J. Hofer, PRA, 2010
W. Liang, Opt Lett., 2011

Brillouin Lasers



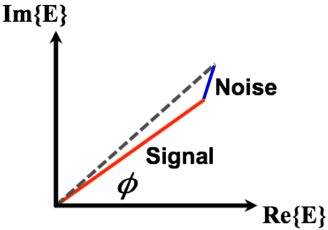


Gain Process

- Brillouin scattering is a nonlinear process where a photon scatters off of a propagating phonon resulting in a backscattered photon which Doppler shifted due to the movement of the phonon.
- SBS and pump fields interfere to drive the phonons to stimulate additional Brillouin scattering.

Why SBS Lasers?

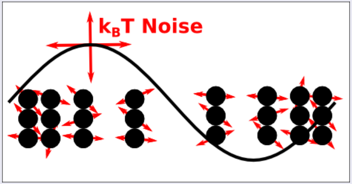
Because they have a high signal to noise ratio!



SBS Laser Noise

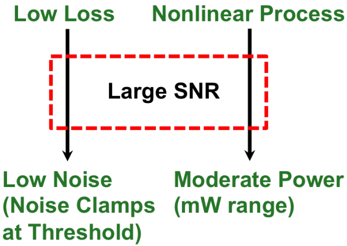
SBS laser noise is governed by thermal fluctuations which are much larger than the energy of the phonons.

$$\frac{h\nu}{k_B T} << 1$$



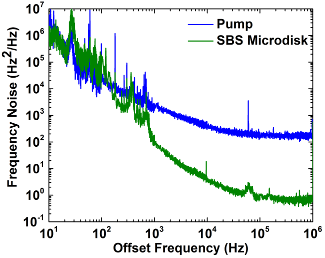
SBS Lasers in Microresonators

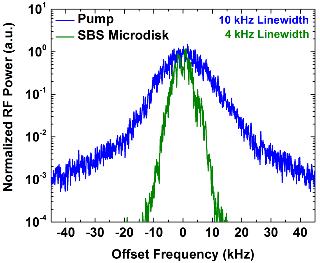
Microresonators are a prime candidate for creating ultra-low-noise lasers using SBS, because of their ultra-high Q.

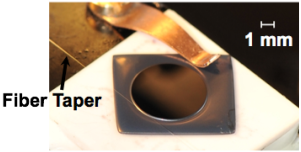


- Their low loss means a lower gain level at steady state operation.
- Lower gain threshold allows for less thermal noise to be added to the signal.
- Non-linear process lead to high signal power.

SBS Laser in Microdisk







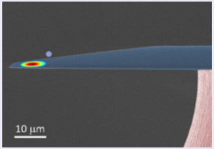
Previous Microdisk Work

- We measured a reduction in noise level by generating an SBS laser within a microdisk.
- This system has been shown to be tunable up to THz.
- This SBS laser has be referenced to a cavity for further noise reduction.

Increasing Mode Volume

Moving from a Microdisk to a Microrod

- Microdisk thickness of $\approx 10\mu m$



H. Lee, Nature Photonics, 2012

- Microrod thickness of $\approx 100\mu m$

$$S_{\bar{u}}(\Omega) \propto V_m^{-1}$$

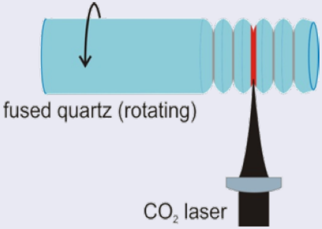
A. Matsko, J. Opt. Soc. Am. B, 2007

- By increasing mode volume we reduce the amount of thermal fluctuations.

Silica Microrod Resonators

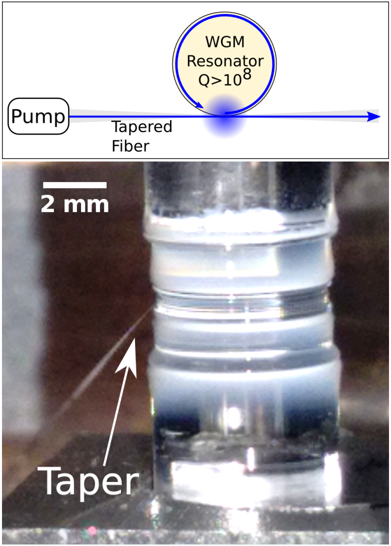
CO_2 Laser Machining Microrods

- Fabrication time on the order of minutes
- Material cost of $\approx \$0.05$ per resonator
- Allows for resonators with larger mode volume



S. Papp, PRX, 2013

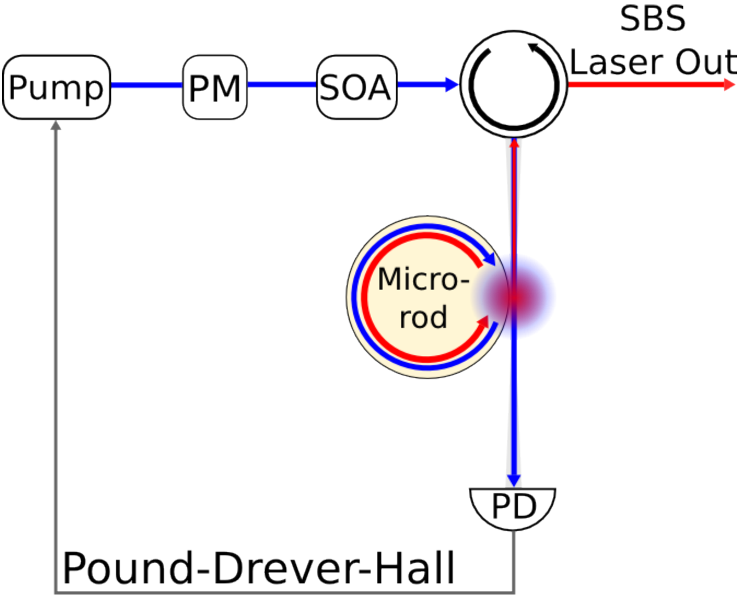
Apparatus



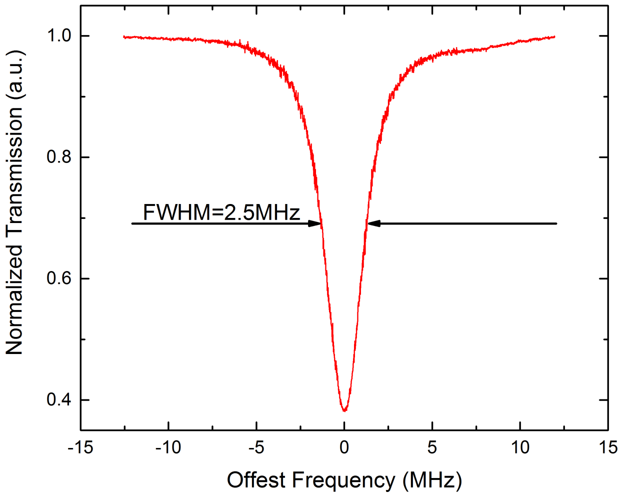
Fiber Coupling

- We pull a single mode optical fiber to form a taper with a waist on the order of the wavelength our light.
- With a fiber smaller than the optical mode we are able to overlap modes between the taper and the resonator.
- This allows for a simple fiber integrated system.

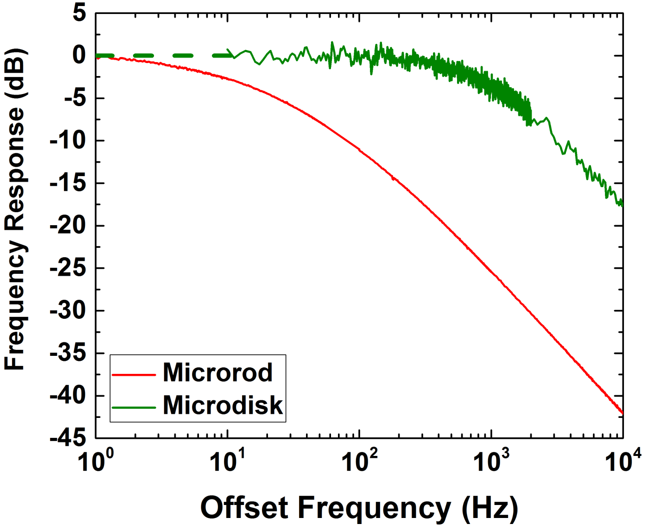
Apparatus Schematic



SBS Generating Resonate Mode Trace



Thermal Response of Microrod Resonators



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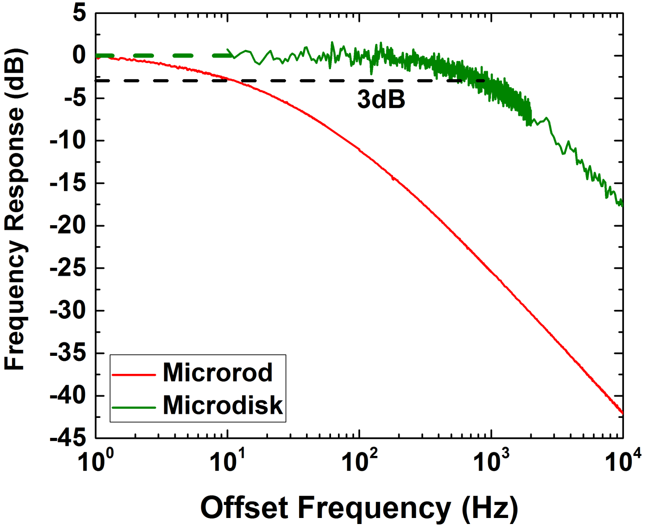
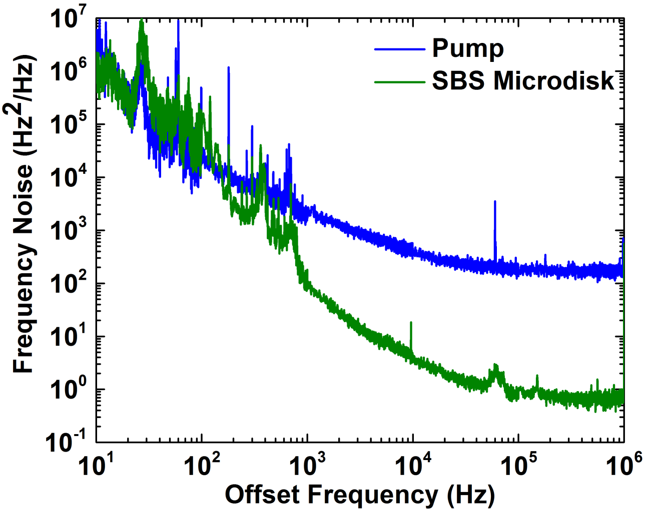


SBS Microrod Laser Frequency Noise



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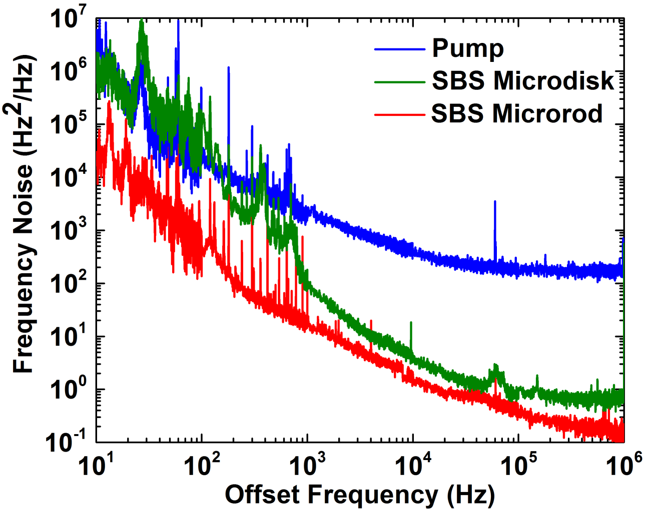
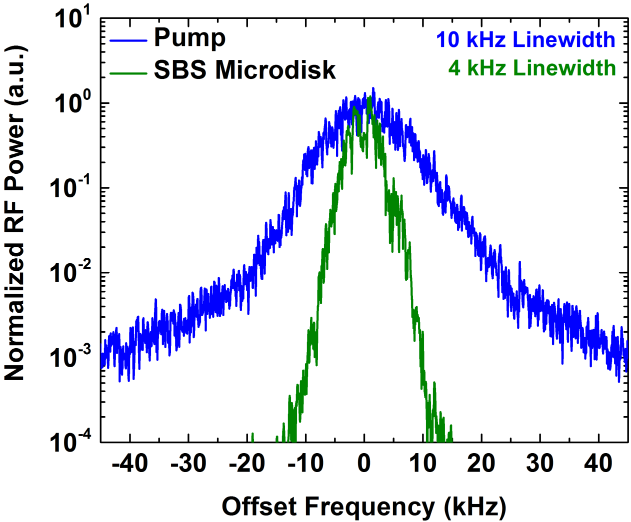
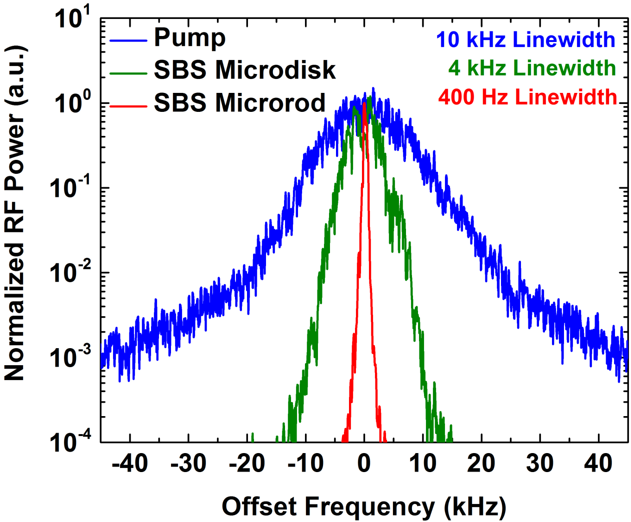


SBS Microrod Laser RF Spectrum



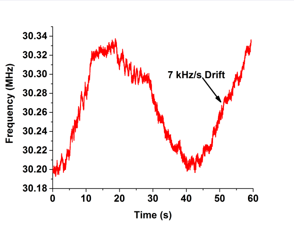
SBS Microrod Laser RF Spectrum



Summary of Results

- We observed a two order reduction in noise from the SBS microdisk by changing to the microrod
- We observed an order reduction in linewidth from the SBS microdisk as well

Future Research Directions



- We have observed a free running thermal drift of $7kHz/s$ and would like to make efforts to reduce the drift.

Acknowledgments

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The NIST Optical Frequency Measurement Lab

- Fred Baynes
- Katja Beha
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Questions?

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Experiment

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