

Microrod
Lasing

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Background

Experiment

Results

Conclusions

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

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September 10, 2015



Current Laser Technology

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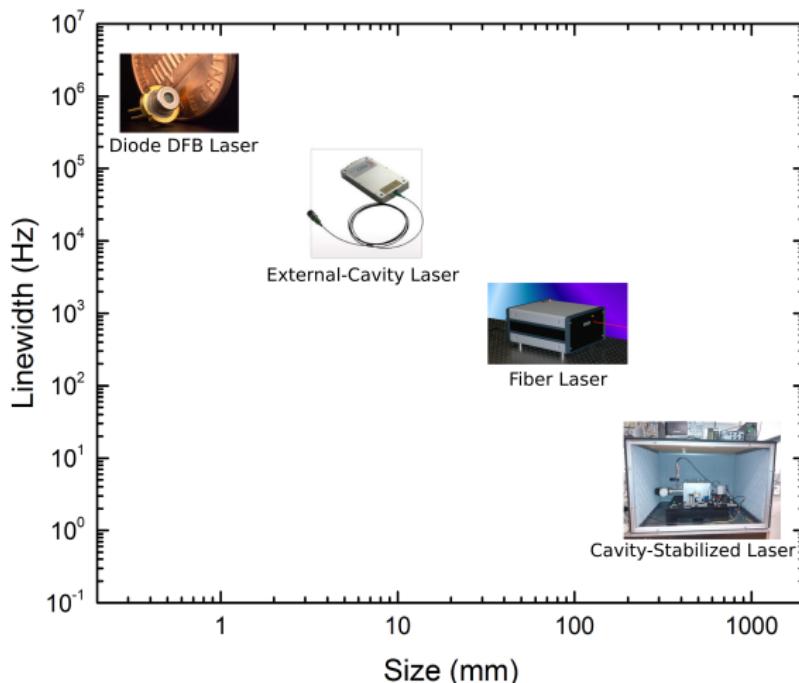
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As lasers increase in stability they increase in size.



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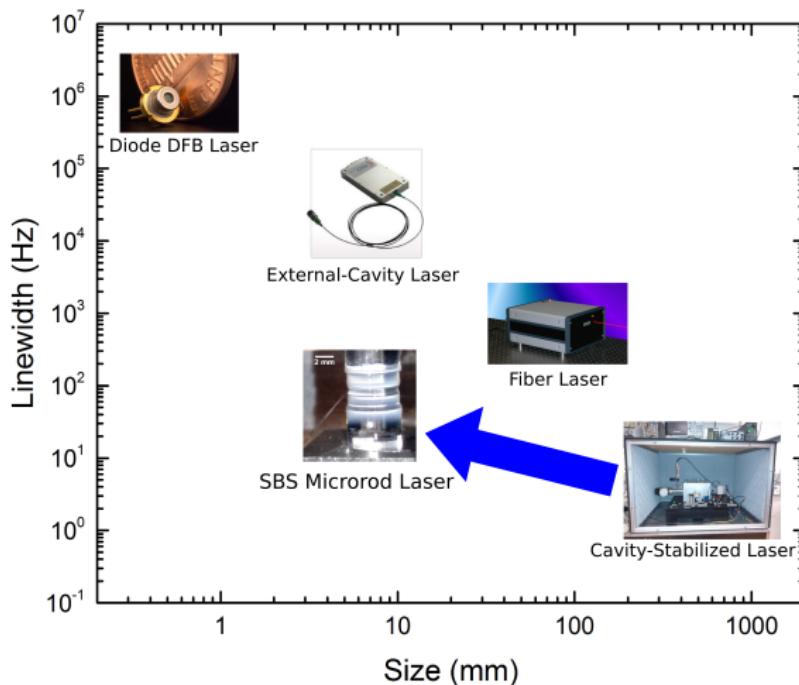
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Whispering Gallery Mode Resonators

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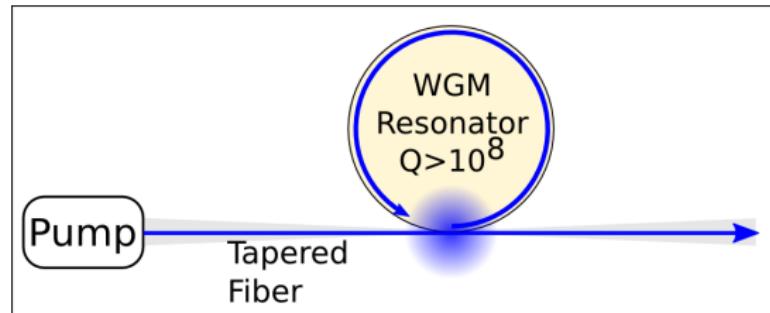
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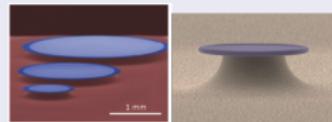
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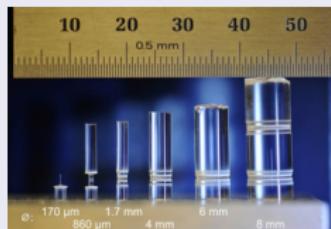


Silica Microdisk



H. Lee, Nature Photon,
2012

Silica Microrod



P. Del'Haye, APL, 2013

CaF₂ Resonator



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

Brillouin Lasers

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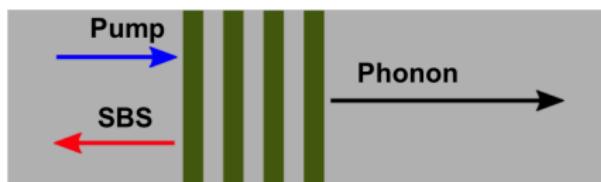
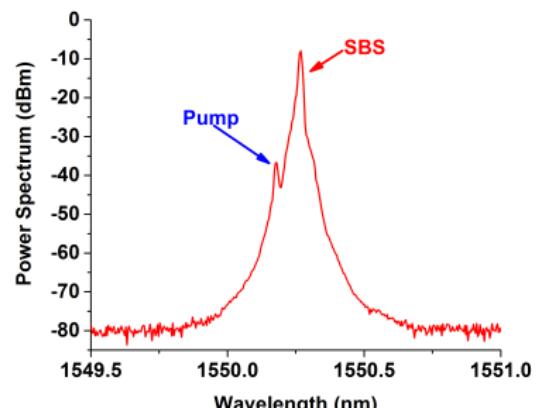
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Gain Process

- 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?

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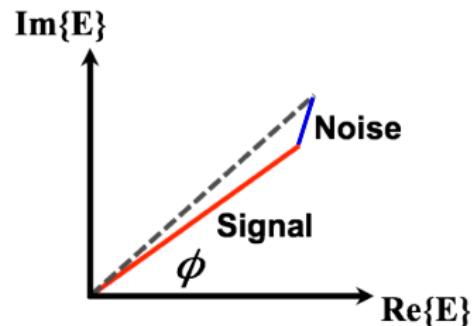
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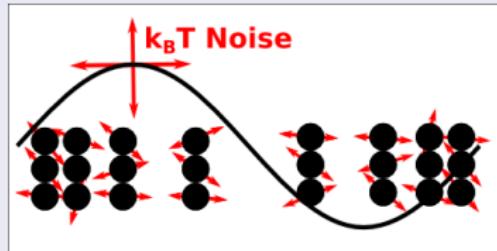
Because they have a high signal
to noise ratio!



SBS Laser Noise

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

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



SBS Lasers in Microresonators

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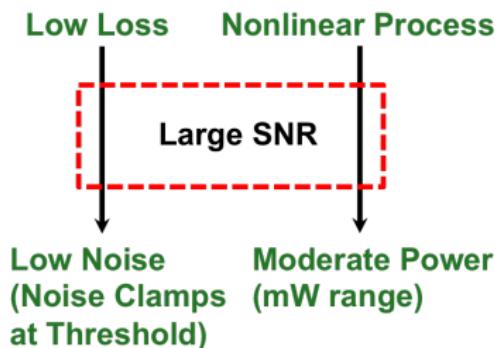
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Microresonators are a prime candidate for creating ultra-low-noise lasers using SBS, because of their ultra-high Q.



- 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

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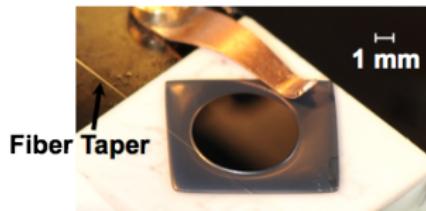
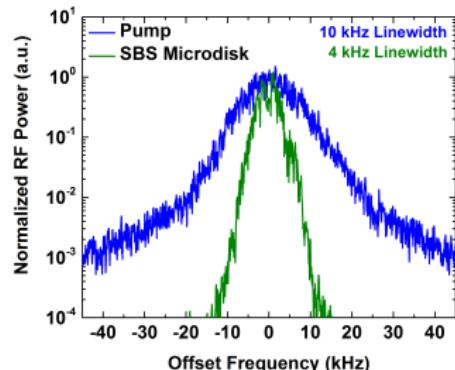
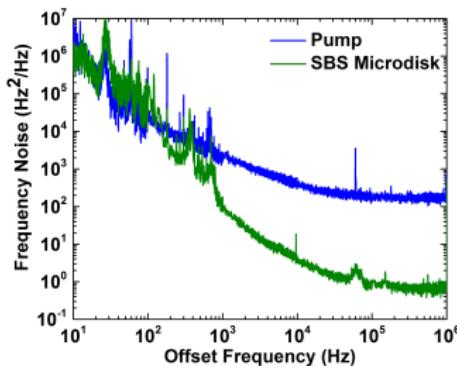
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Previous Microdisk Work

- 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 been referenced to a cavity for further noise reduction.

Increasing Mode Volume

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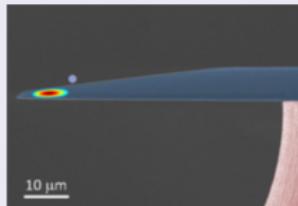
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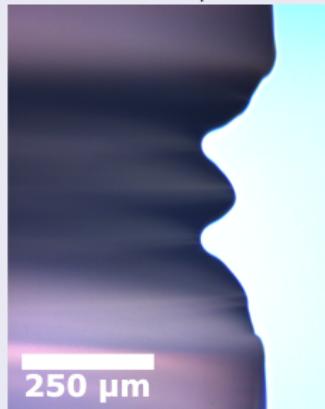
Moving from a Microdisk to a Microrod

- 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.

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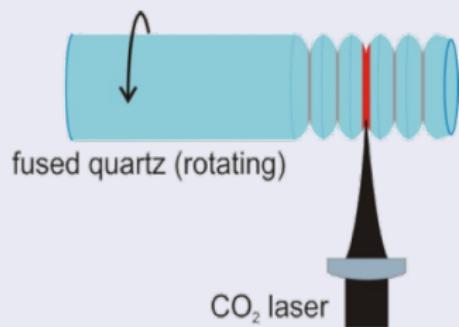
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CO₂ Laser Machining Microrods

- 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

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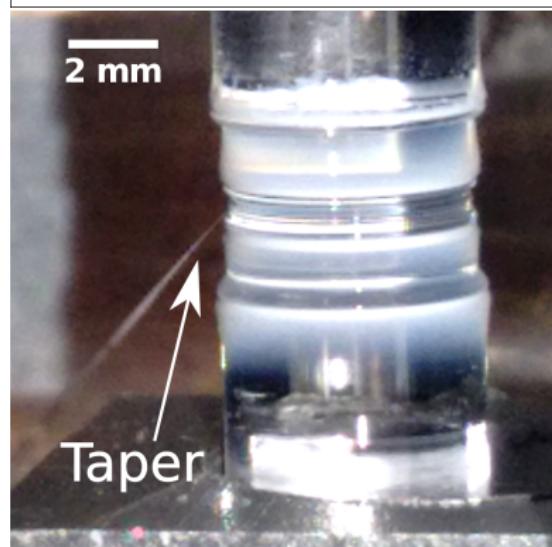
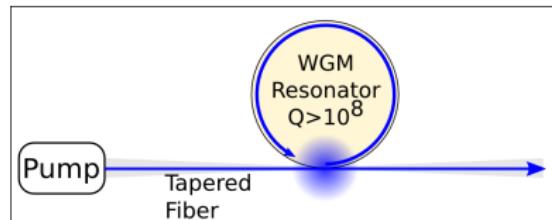
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Fiber Coupling

- 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

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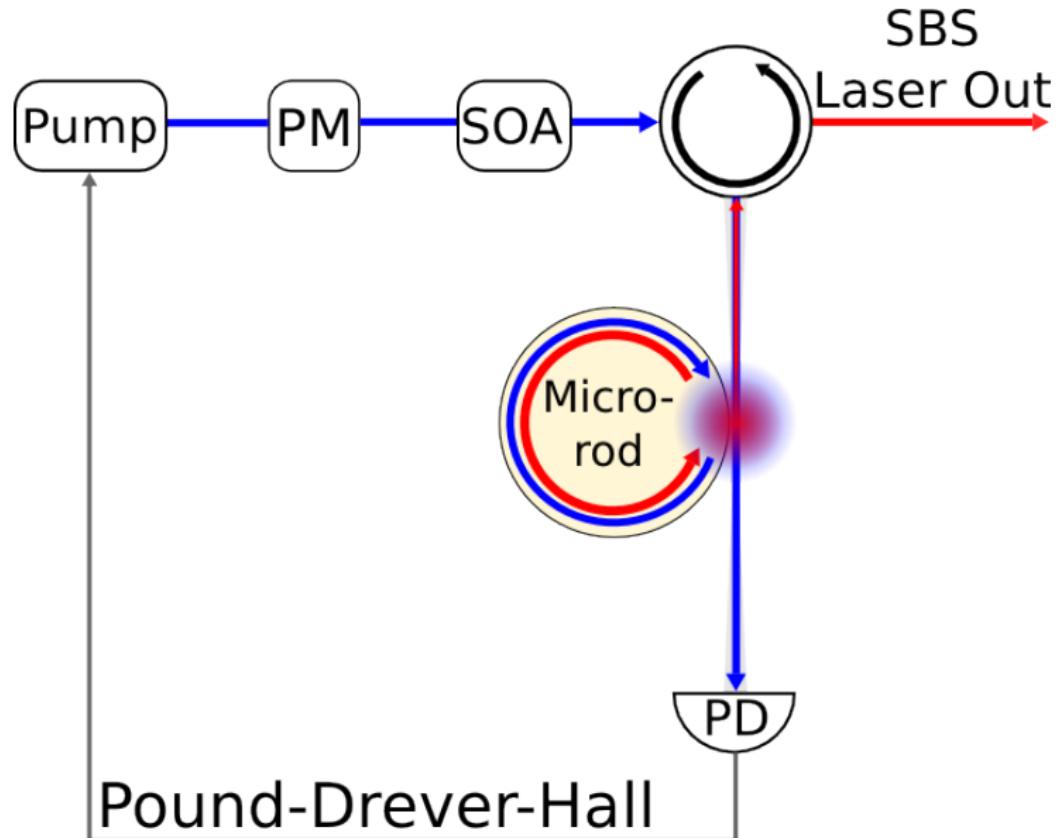
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SBS Microrod Laser Frequency Noise

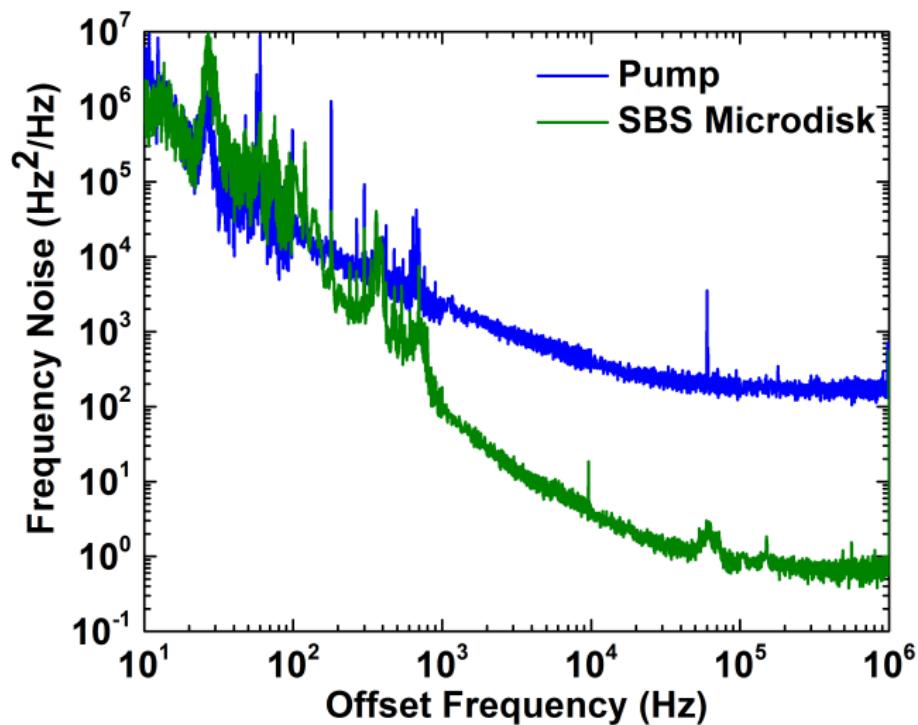
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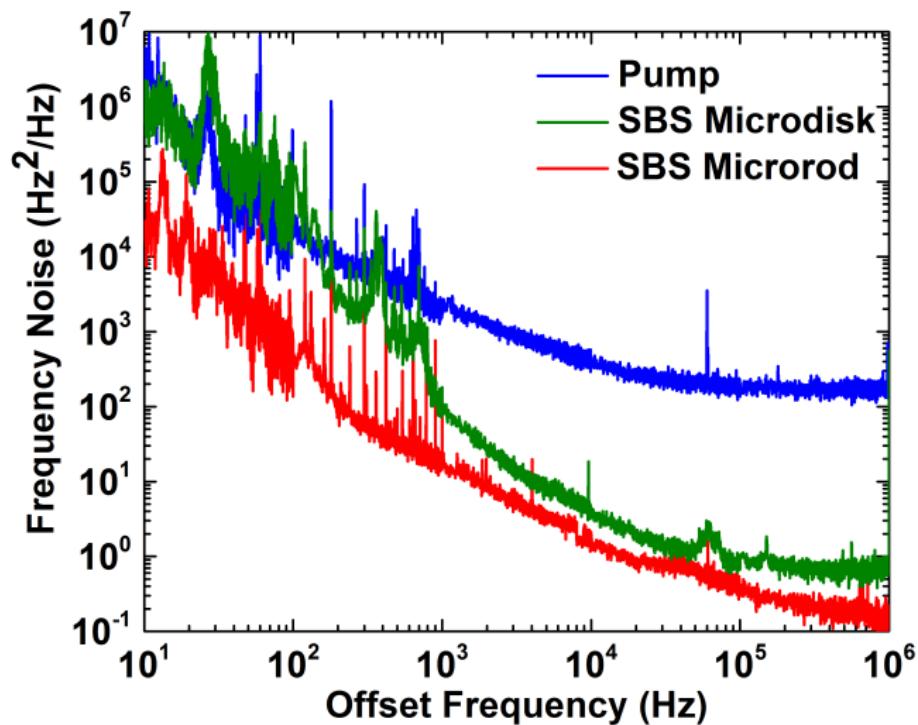


SBS Microrod Laser Frequency Noise

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SBS Microrod Laser RF Spectrum

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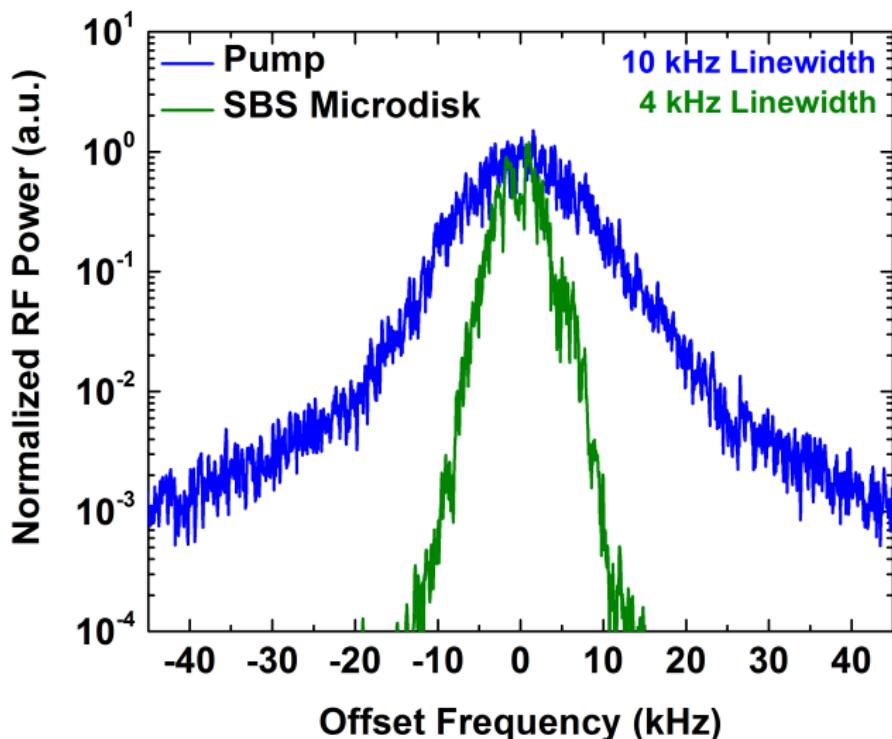
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SBS Microrod Laser RF Spectrum

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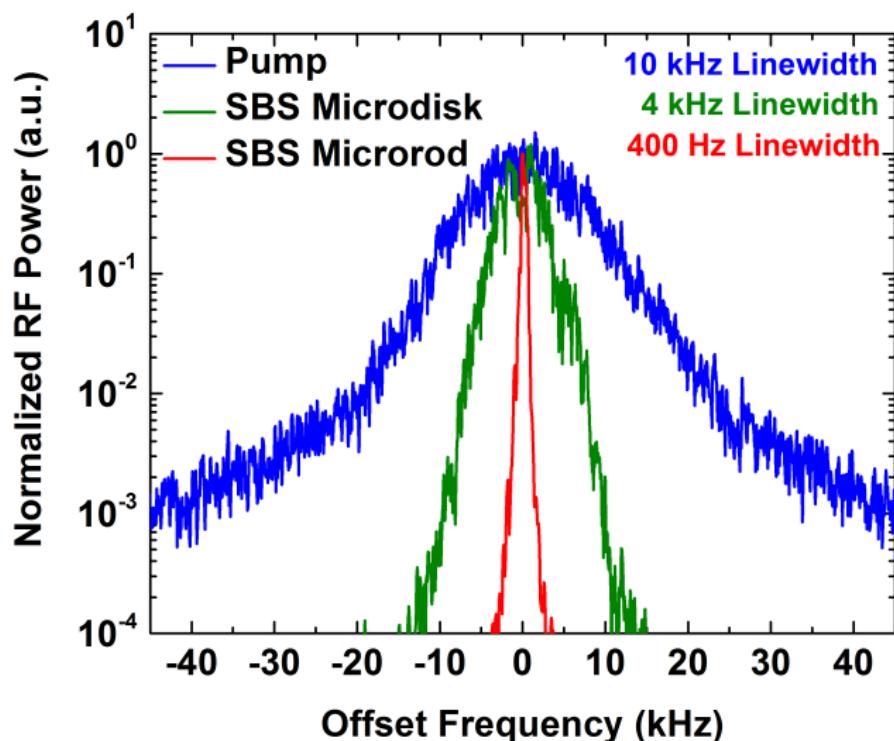
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Summary of Results

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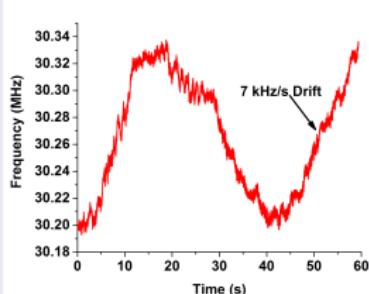
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- We observed a two order reduction in noise from the SBS microdisk by changing to the microrod
- We observed an order reduction in linewidth from the SBS microdisk as well

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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- Scott Papp
- Frank Quinlan

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- Kerry Vahala

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Questions?

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