High-Transmission Fibre Ring Resonator for Spectral Filtering of Master Oscillator Power Amplifiers

J. L. H. Mik[1,2,3], B. M. Sparkes[1,3], C. Perrella[1,3], P. S. Light[1,3], S. Ng[1,2,3], A. N. Luiten[1,3], and D. J. Ottaway[1,2,3]

1. Institute for Photonics and Advanced Sensing, Univesity of Adelaide, SA 5005 Australia
2. ARC Centre of Excellence for Gravitational Wave Discovery (OzGrav), University of Adelaide Node, Adelaide, SA 5005 Australia
3. School of Physical Sciences, Univeristy of Adelaide, SA 5005 Australia

Motivation

Why do we want high power, stable and low noise lasers?

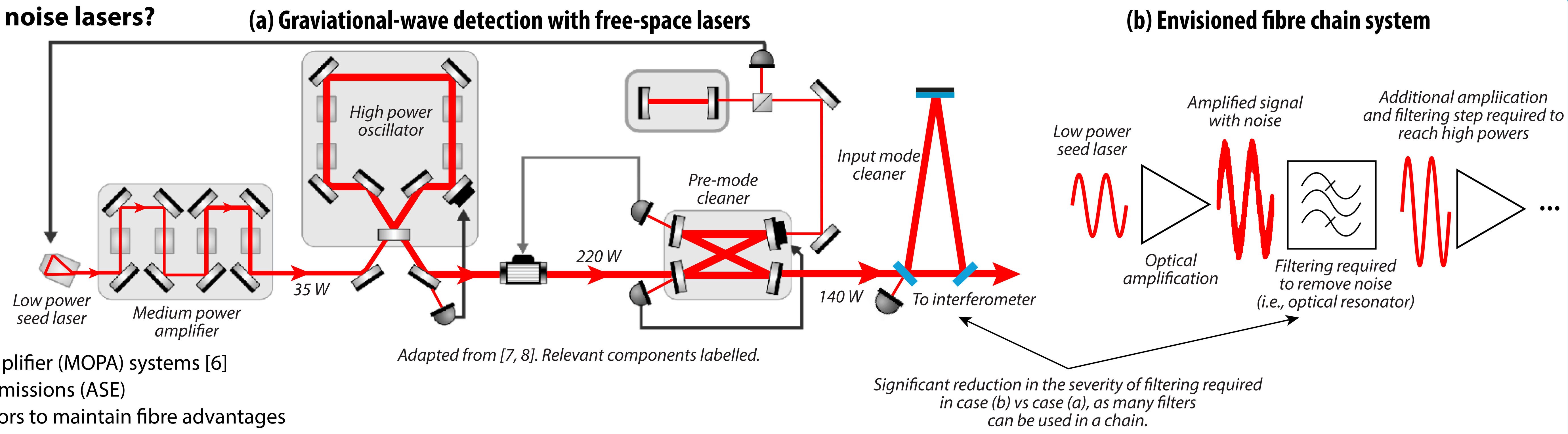
- Lidar [1]
- Optical communication [2]
- Trapped-ion quantum computing [3]
- Gravitational-wave detection [4]

Why do we want high power Fibre lasers?

- Single-mode emission
- Compact and robust
- Minimal alignment

Why do we want a fibre ring resonator?

- Single frequency fibre lasers produce ~100 mW [5]
- Amplifed in stages through master oscillator power amplifier (MOPA) systems [6]
- Need filter cavities to remove amplified spontaneous emissions (ASE)
- If fibre-based lasers are used, want fibre-based resonators to maintain fibre advantages



1 All-Fibre Resonator Options

Fibre Bragg Gratings [9, 10]

- Low bandwidth (~nm)
- Extra isolation required
- No dedicated reference port

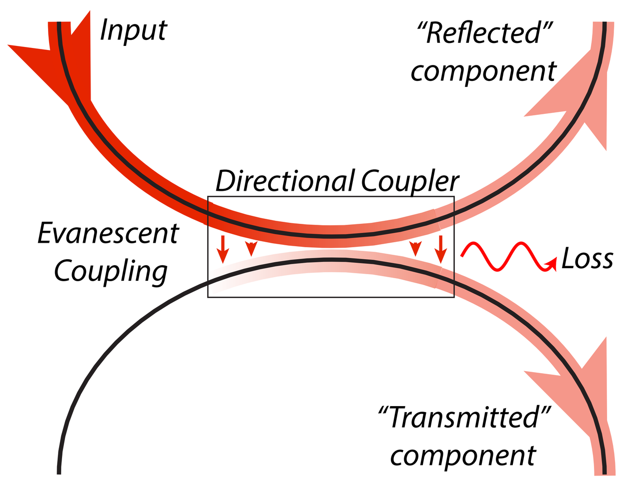
Single Directional Coupler systems [11]

- Notch-type filter
- Narrow-band suppression

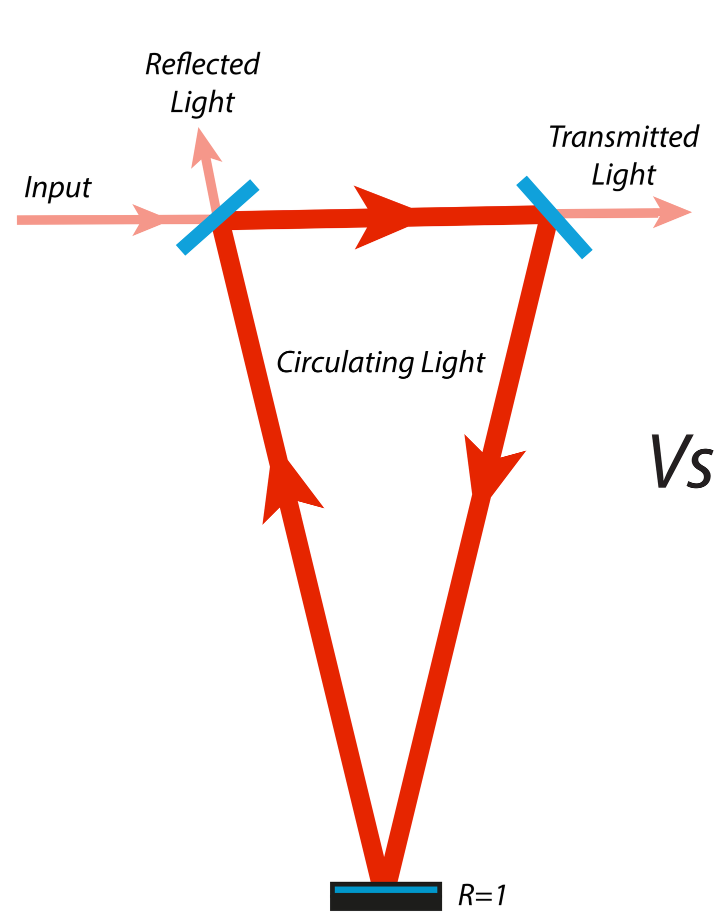
Double Directional Coupler Systems [12, 13]

- Inherent optical isolation
- Wide-band suppression
- Current implentations <50% transmission

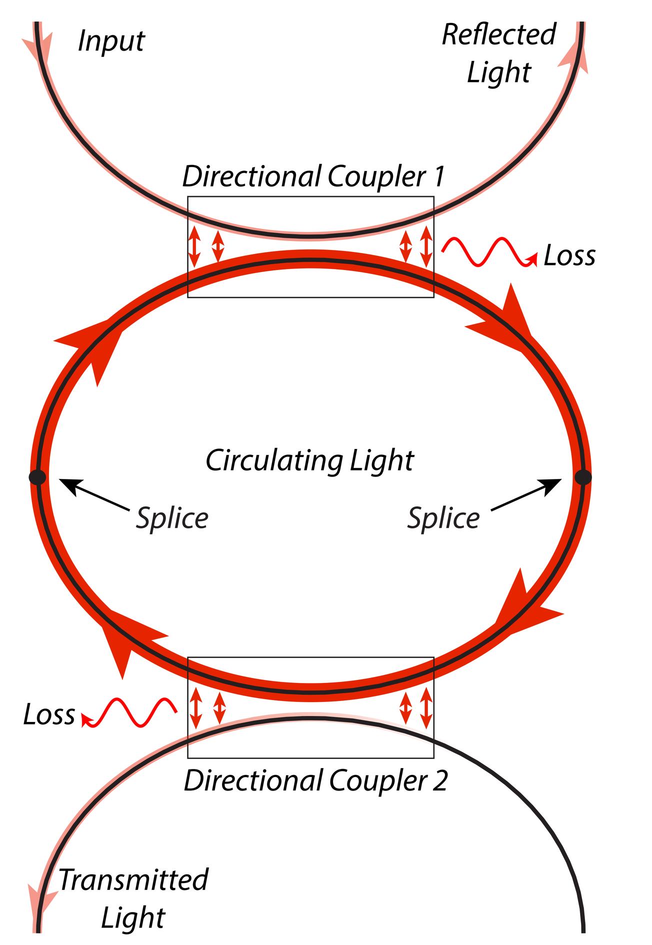
→ *Need to significantly reduce loss!*



2 Compare the Resonators



Vs



Resonator Equations [14]

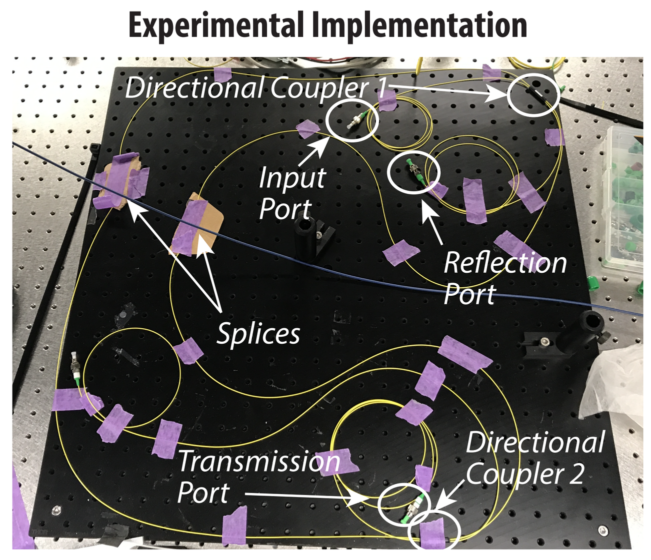
Reflectivity; Efficiency of couplers (1-loss)

$$I_{\text{reflected}} = \frac{R(1-\mathcal{V})^2 + 4R\mathcal{V}\sin^2(kp)}{(1-R\mathcal{V})^2 + 4R\mathcal{V}\sin^2(kp)}$$

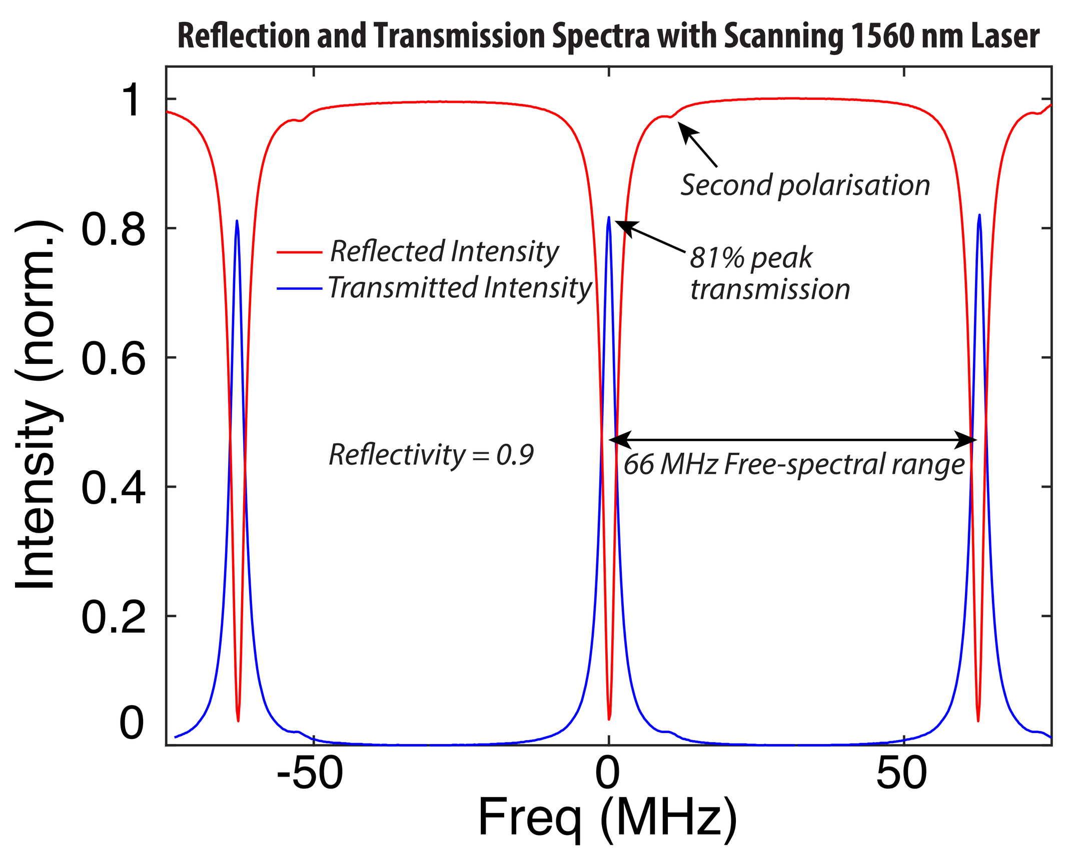
$$I_{\text{transmitted}} = \frac{(1-R)^2\mathcal{V}}{(1-R\mathcal{V})^2 + 4R\mathcal{V}\sin^2(kp)}$$

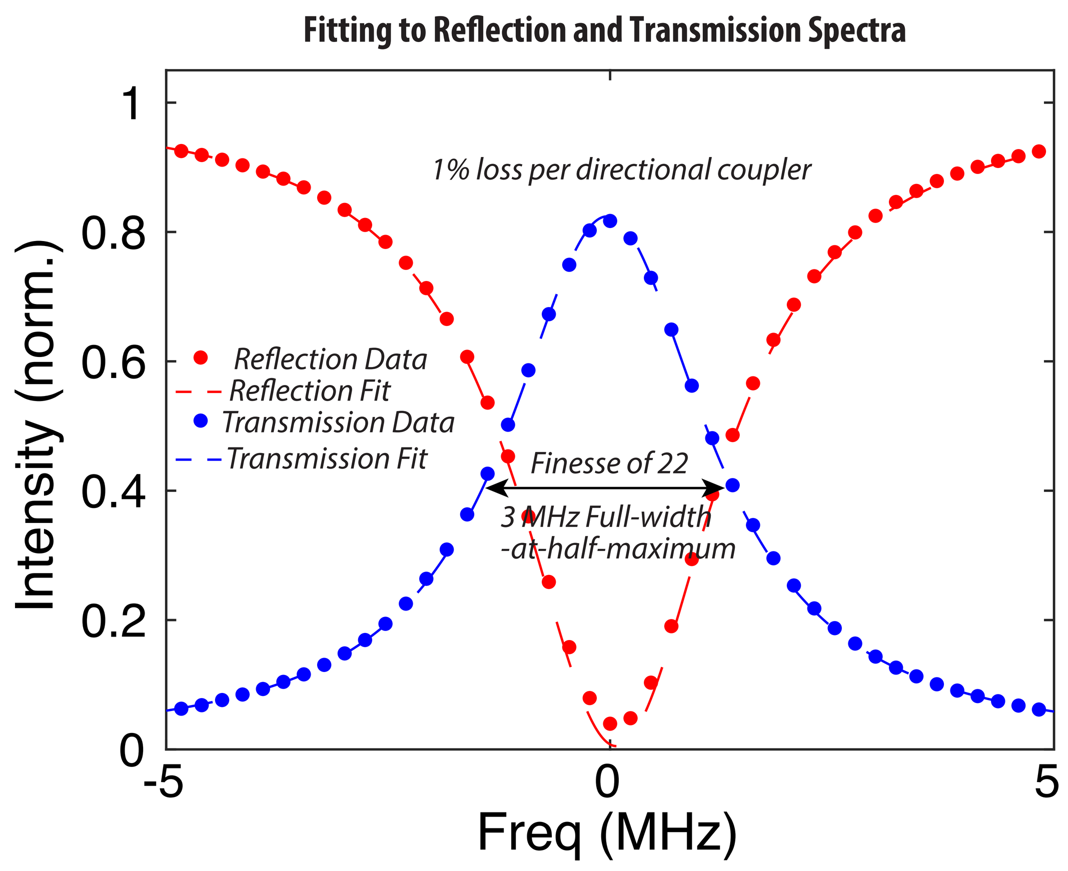
Wave number; Perimeter of fibre loop

Experimental Implementation

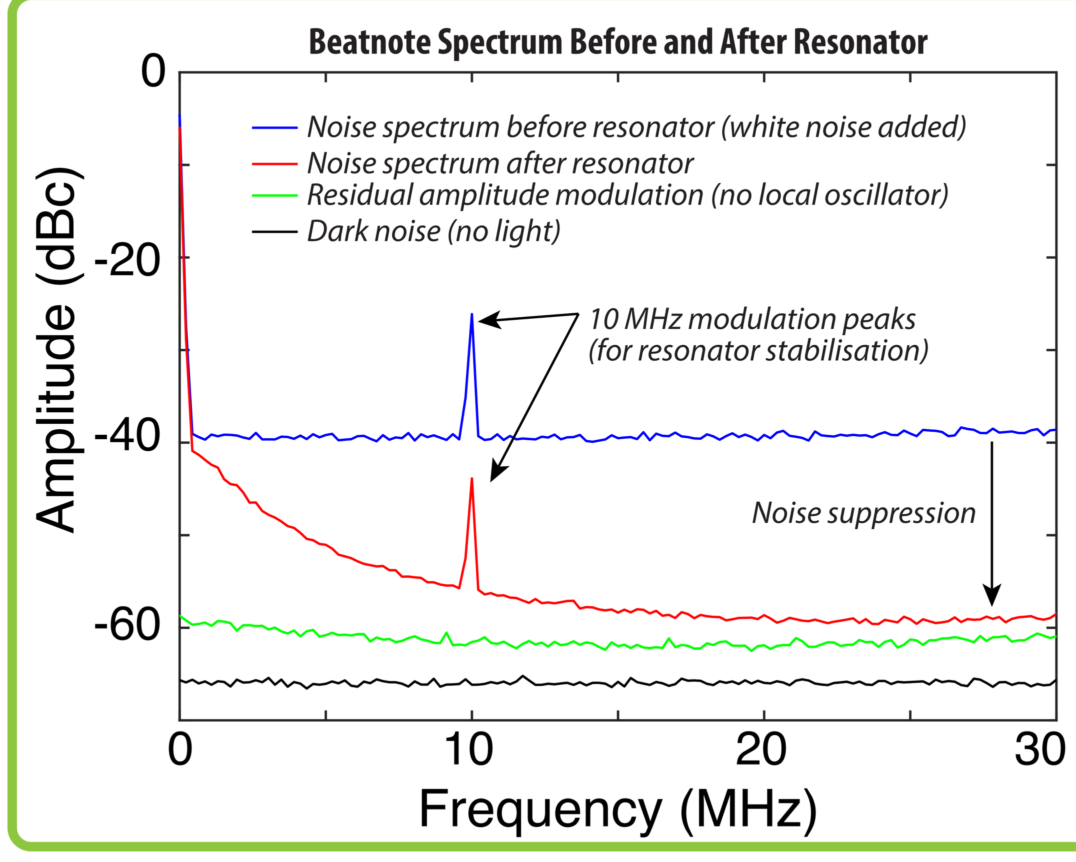


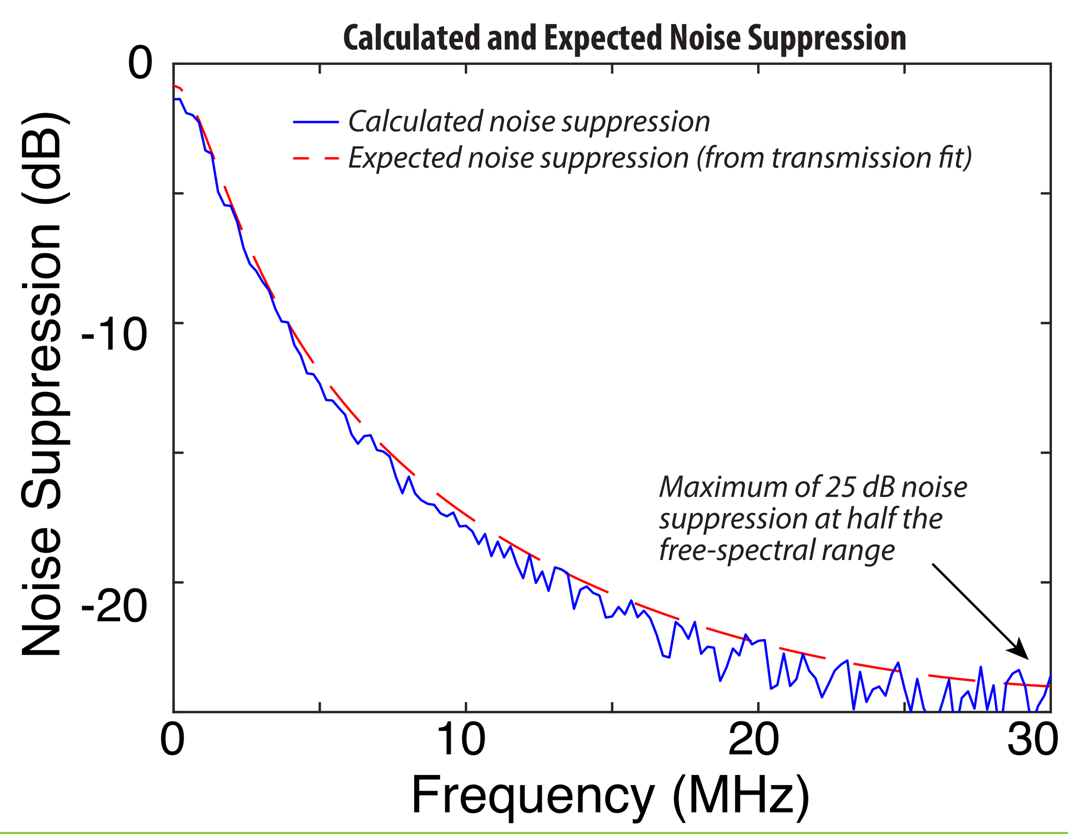
3 Reflection & Transmission





4 Noise Suppression





Conclusions

We have created a fibre-based resonator from commercially-available directional couplers with 80% transmission and 25 dB suppression, making it ideal for removing noise in chained fibre-amplifier system to provide high power, low noise lasers. For instance, by tailoring the resonator fibre length, we will be able to provide maximum suppression at the key gravitational wave measurement frequencies of 9, 36 and 45 MHz [15].

By creating our own directional couplers, we could reduce loss from 1% to 0.1%, increasing transmission to over 90%. This would open up additional applications in quantum optics such as combining & separating optical fields of different wavelengths [16], or create a fibre-based optical parameteric oscillator by combining it with a waveguide-based sources of squeezing [17].

References & Acknowledgements

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