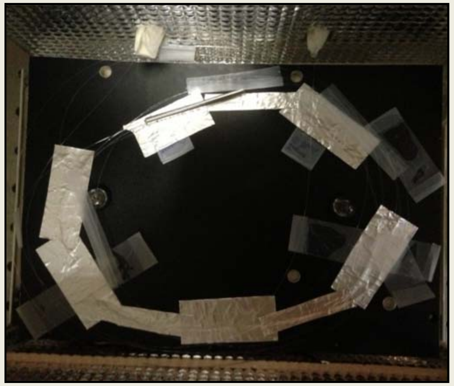
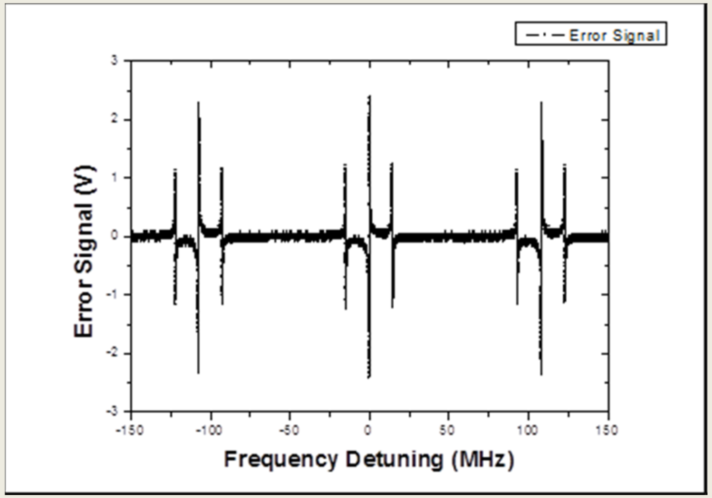
Fiber ring cavity for KAGRA





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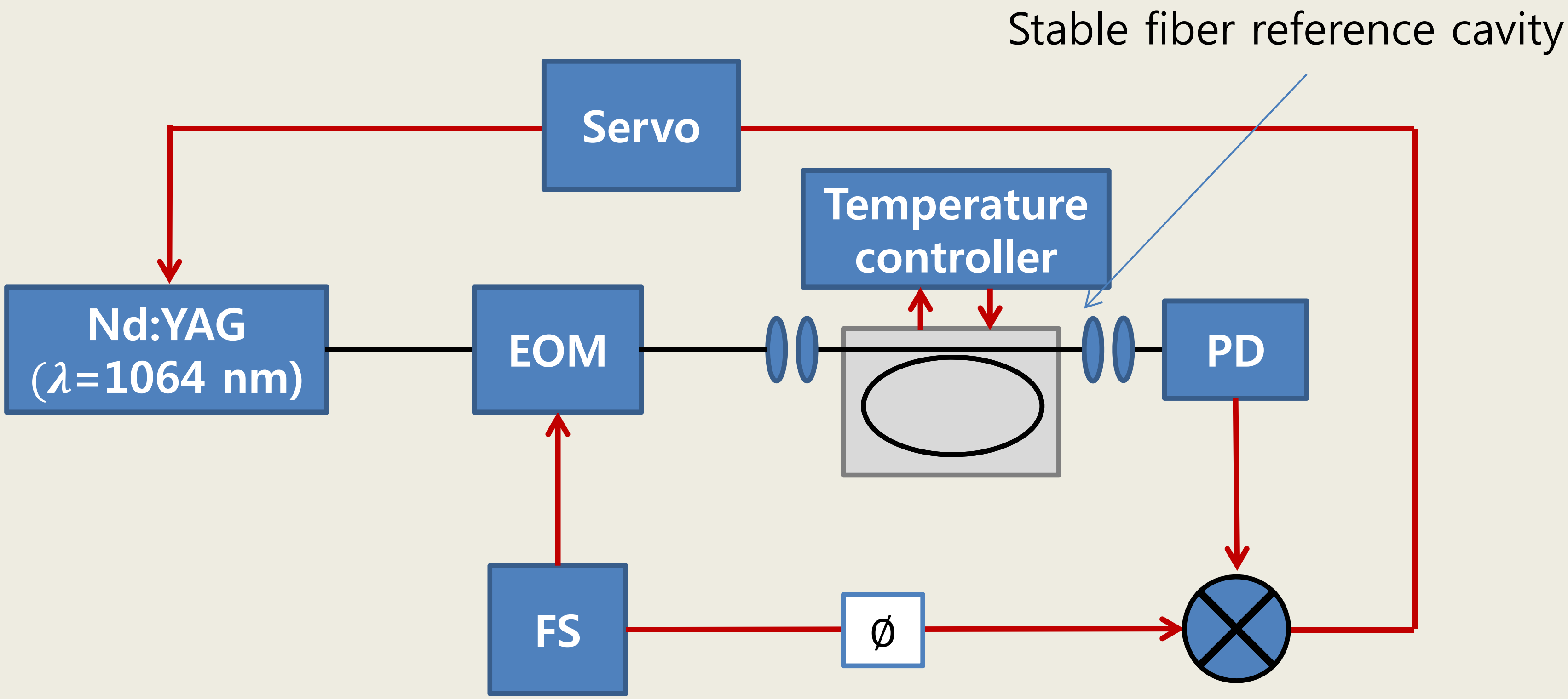
June 23 - August 23, 2013

Outline

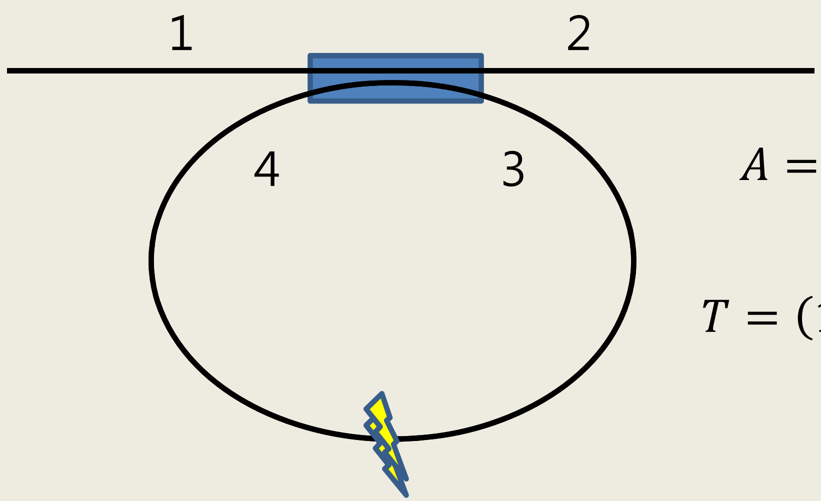
- Experiment outline
- Fiber ring cavity fabrication
- Frequency stabilization of Nd:YAG laser

Experiment outline



Laser frequency stabilization by versatile fiber ring cavity

Fiber Ring Cavity (FRC)



$$A = (1-\kappa)(1-r)(1-a)\, e^{-2\alpha L}$$; loss factor

$$T = (1-r)\left(1 - \frac{\kappa\,(1-\kappa-A)}{(1-\kappa)\,(1+A-2A^{1/2}\mathrm{Cos}[\beta L])}\right)$$

$$f_{\mathrm{FSR}} = \frac{c}{n\,L'}$$

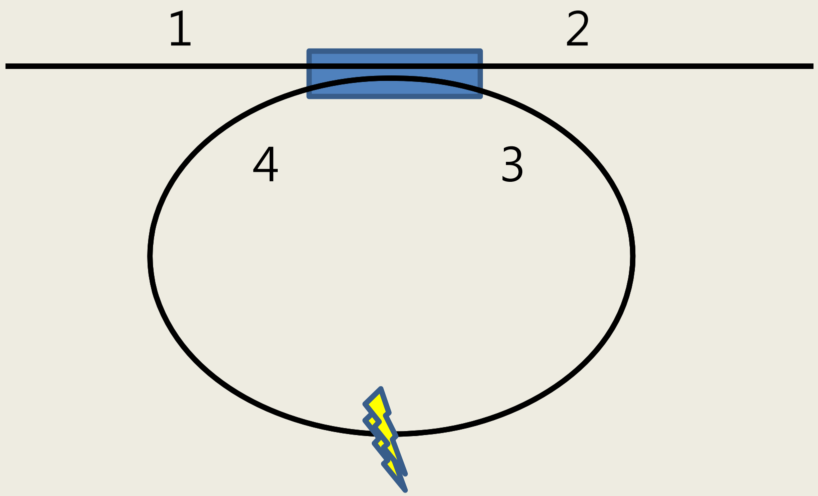
$$\Delta\nu = \frac{c\sqrt{\frac{\left(1-\sqrt{A}\right)^2}{\sqrt{A}}}}{L\,n\,\pi}$$

$$\mathcal{F} = \frac{\pi}{\sqrt{\frac{\left(1-\sqrt{A}\right)^2}{\sqrt{A}}}}$$

κ : Coupling Ratio
r : Insertion Loss
a : Splicing Loss
α : Fiber Loss
L : Cavity Length
β : Wave number

Ref. "All-single-mode fiber resonator", L.F. Stokes, et al., Opt. Lett. 7, 288 (1982).

FRC design parameter



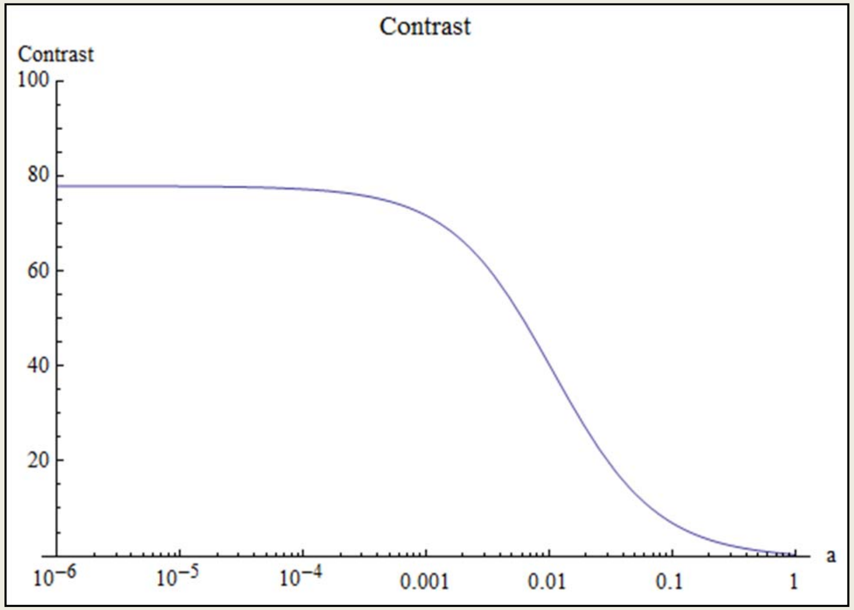
FSR = 100 MHz
$\Delta\nu = 200$ kHz

Design Parameter

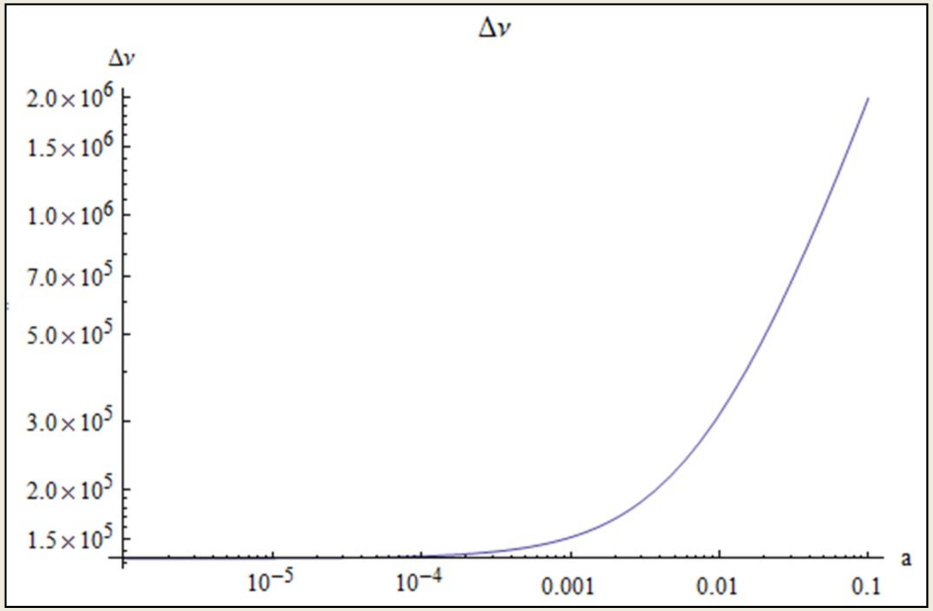
L **: 2 m**	κ **: 0.002**
n : 1.46	r **: 0.003**
α **: 1.5 dB/km**	**FSR : 100 MHz**

κ : Coupling Ratio
r : Insertion Loss
a : Splicing Loss
α : Fiber Loss
L : Cavity Length

FRC simulation

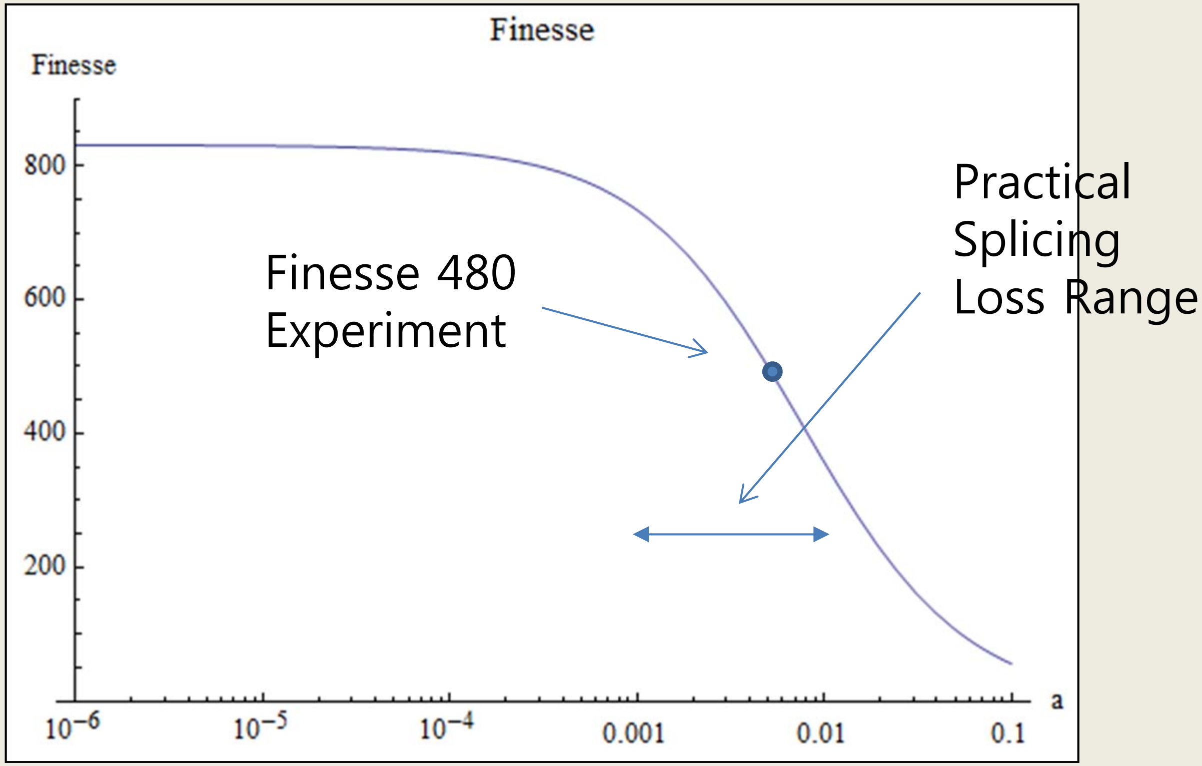


Splicing loss



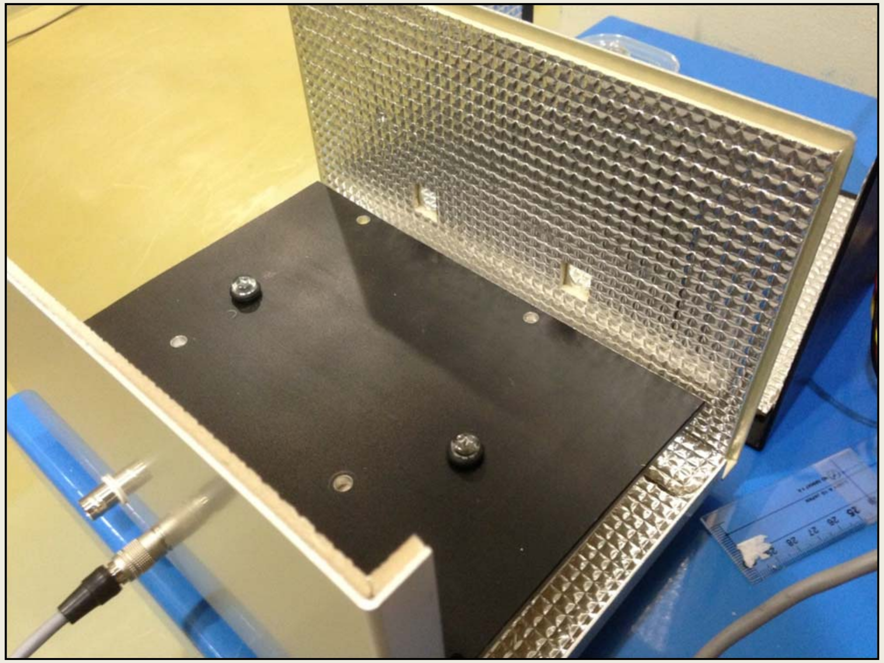
Splicing loss

FRC simulation



Splicing loss

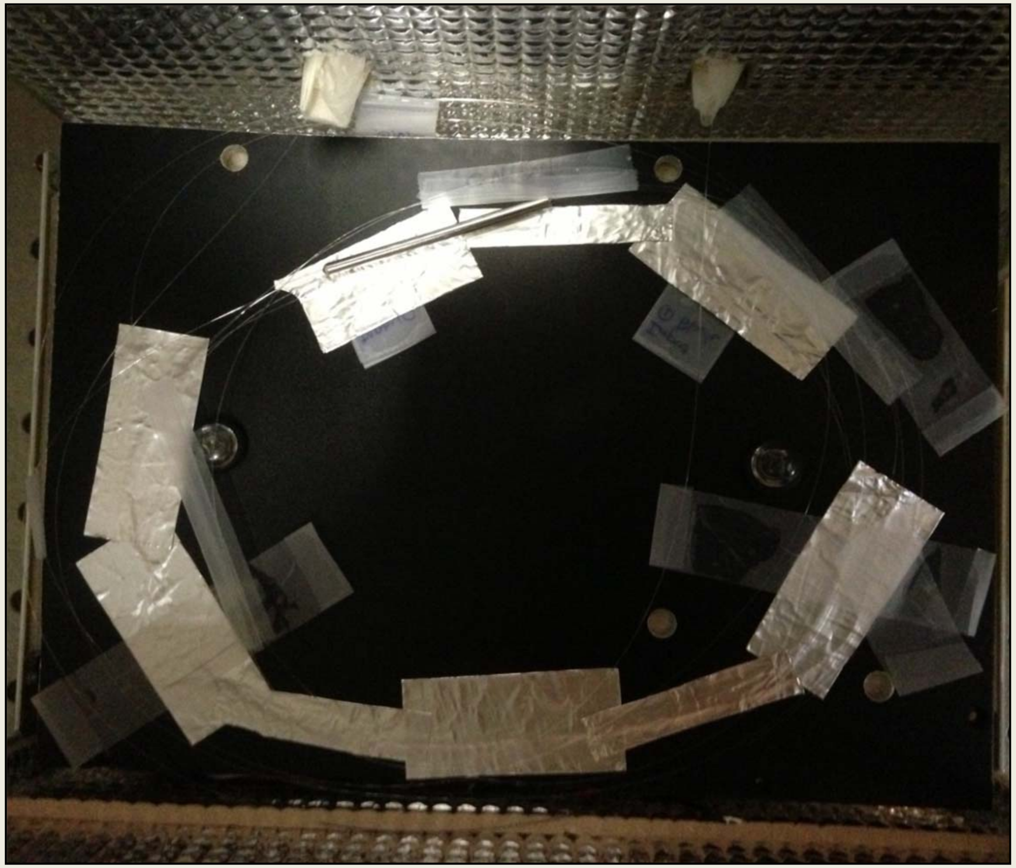
FRC temperature control



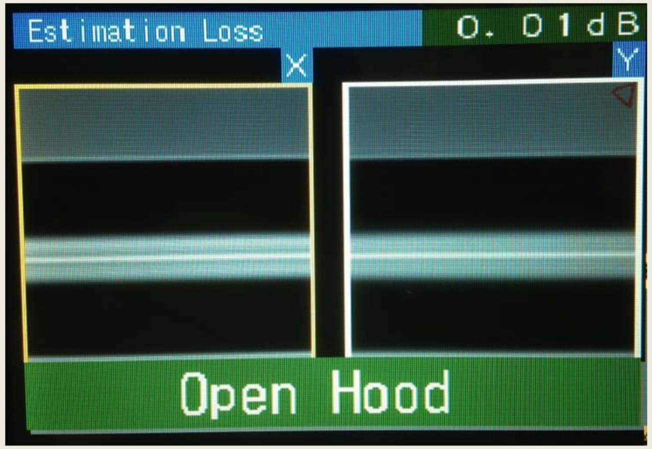
Thermistor : TH10K

$\Delta T \approx \pm 5$ **mK**

FRC fabrication



Micro core
DCM Fusion Splicer Type-39



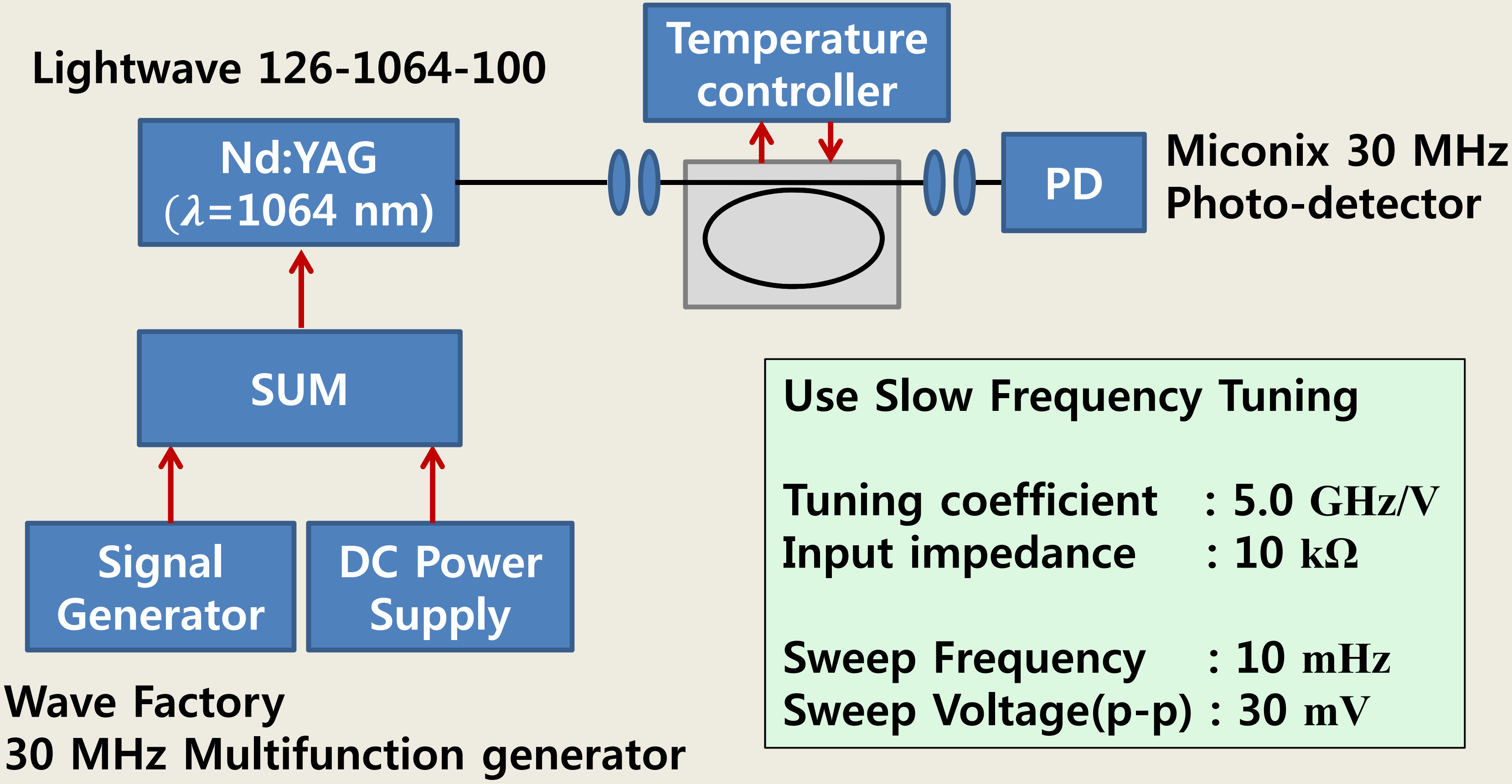
$r \cong 0.0023$

Finesse ≅ 630

OPNETI Single Mode Standard Coupler (99.8 % : 0.2 %)

Courtesy of fiber splicer
Prof. Kobayashi, ISSP

Finesse Measurement

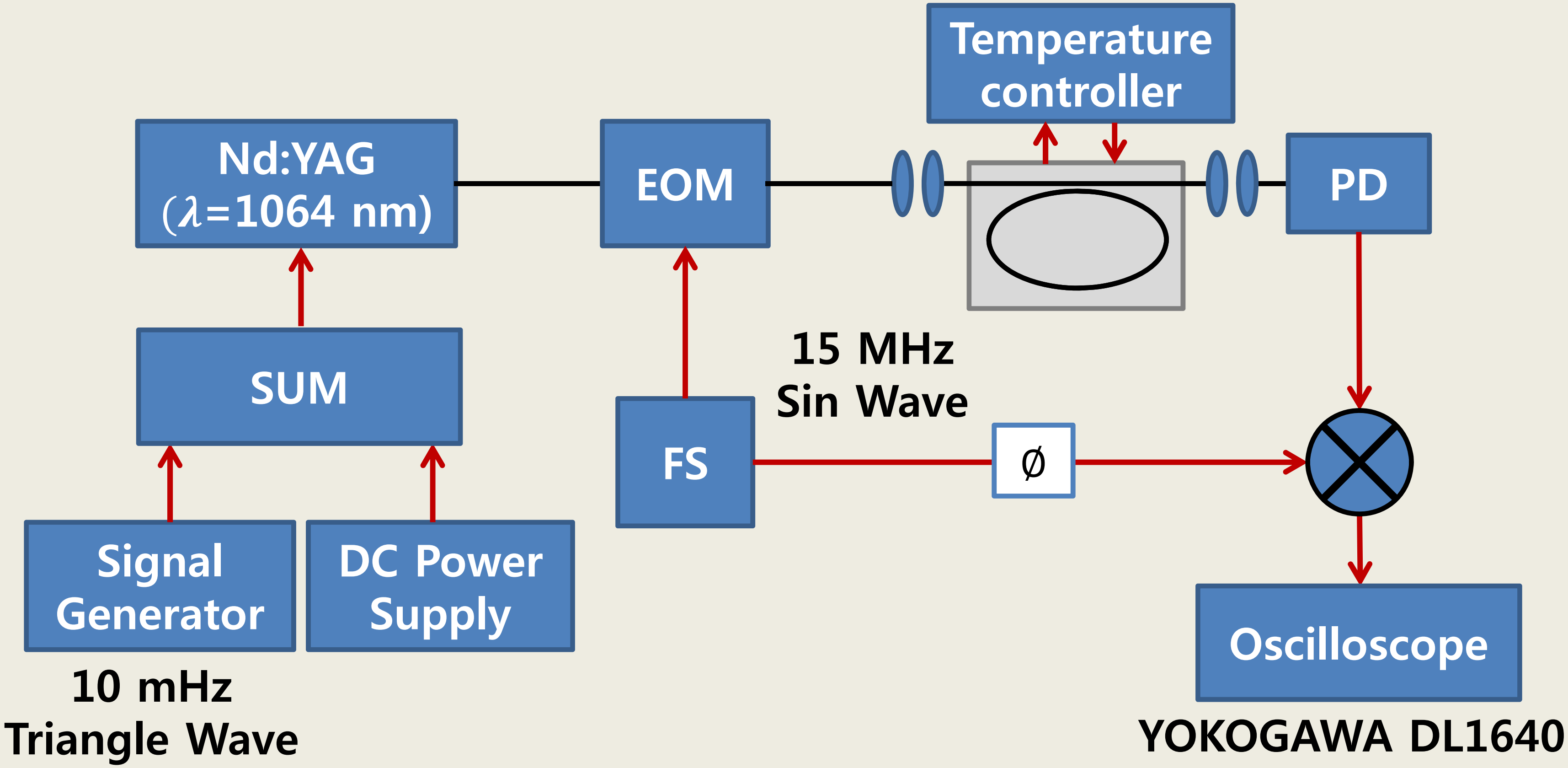


Use Slow Frequency Tuning

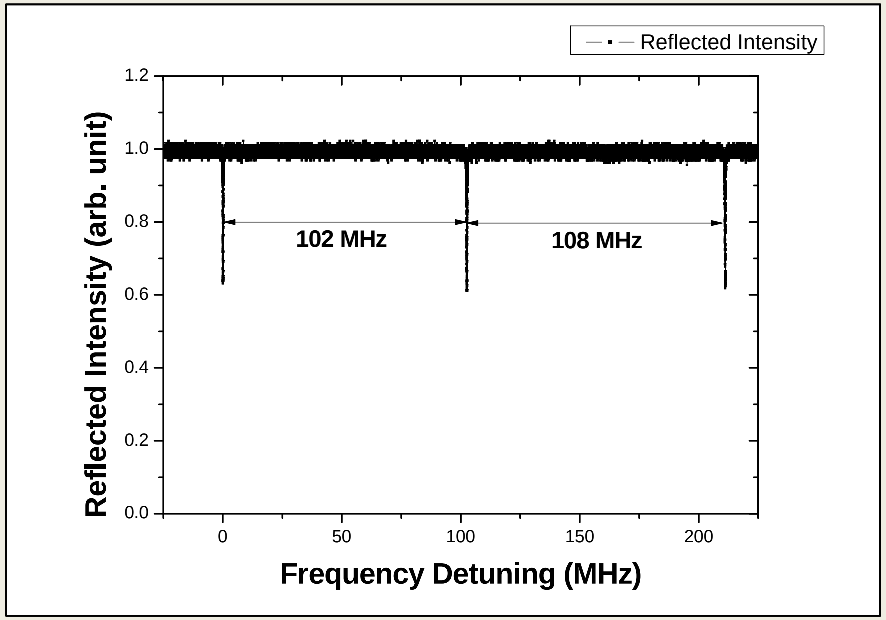
Tuning coefficient : 5.0 GHz/V
Input impedance : 10 kΩ

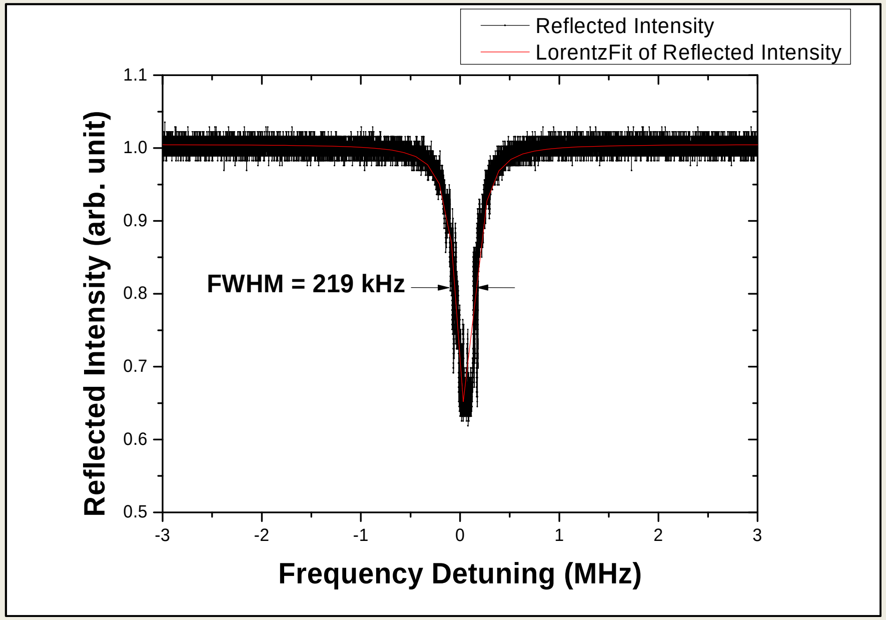
Sweep Frequency : 10 mHz
Sweep Voltage(p-p) : 30 mV

PDF error signal measurement



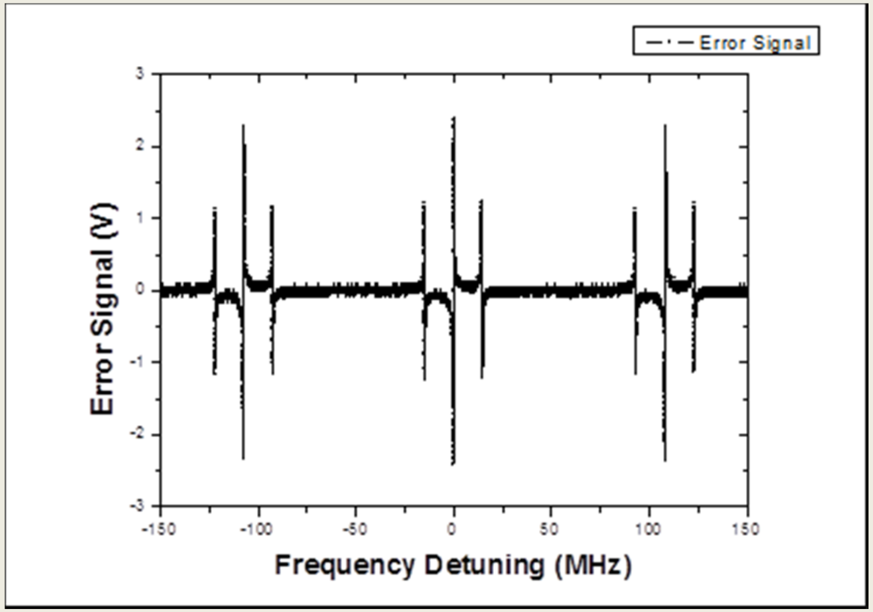
Finesse measurement

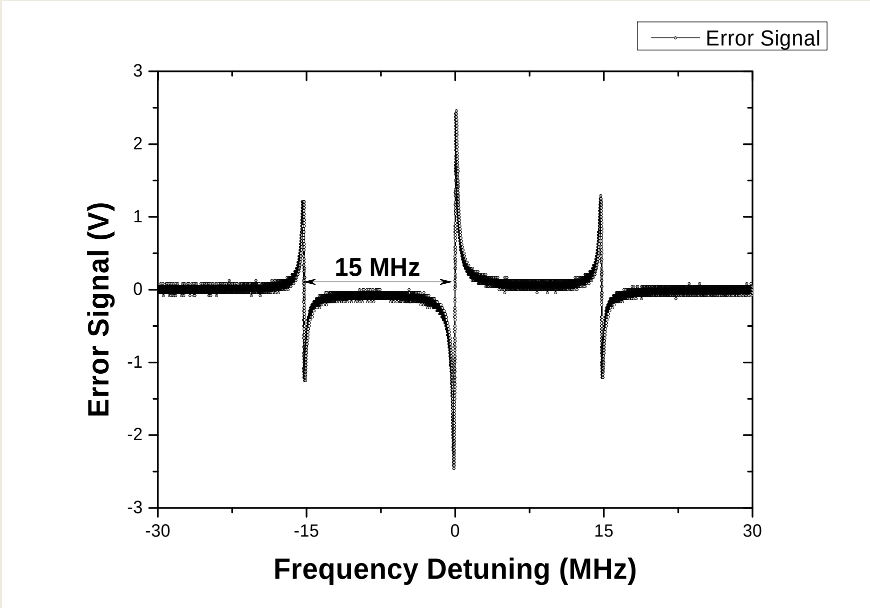




Finesse = 480

Linewidth calibration

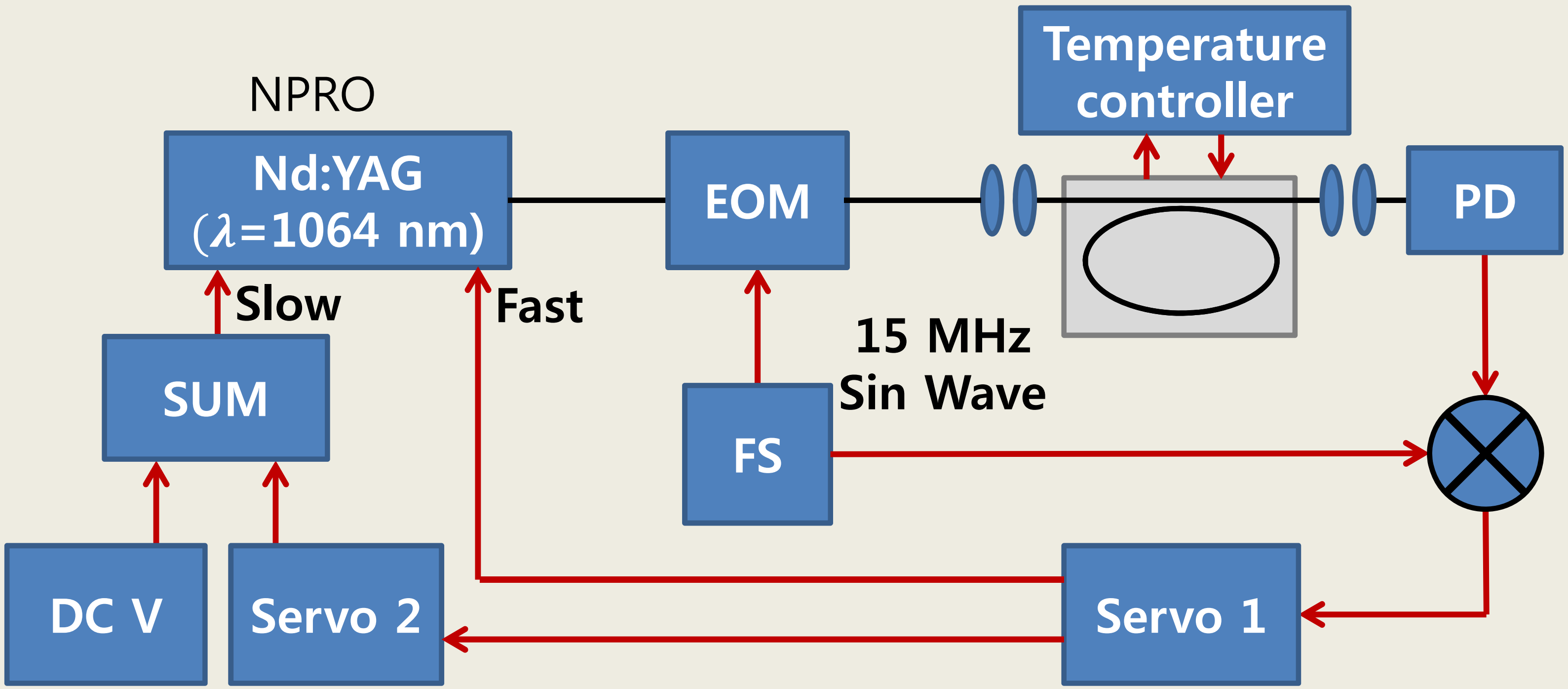




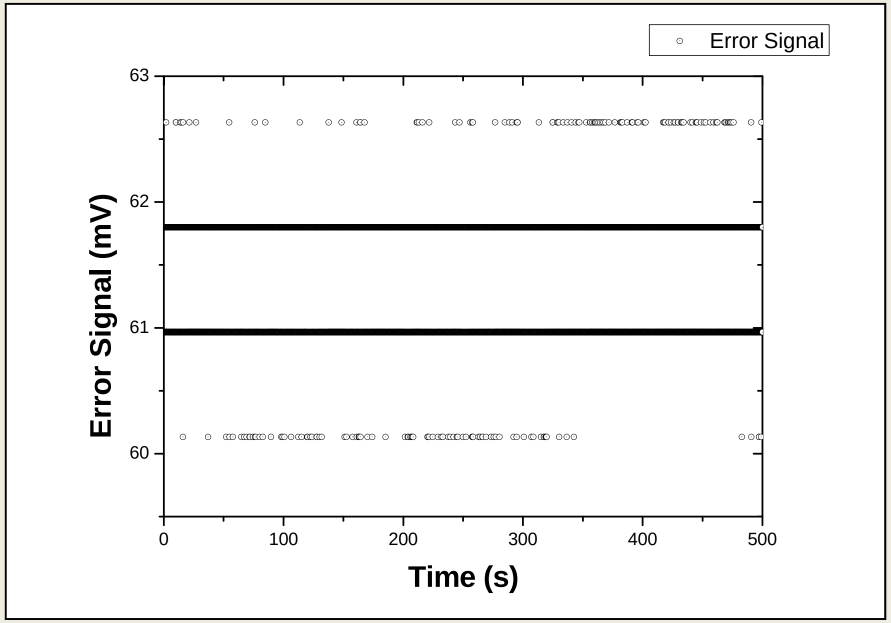
Thermal frequency scanning; nonlinear

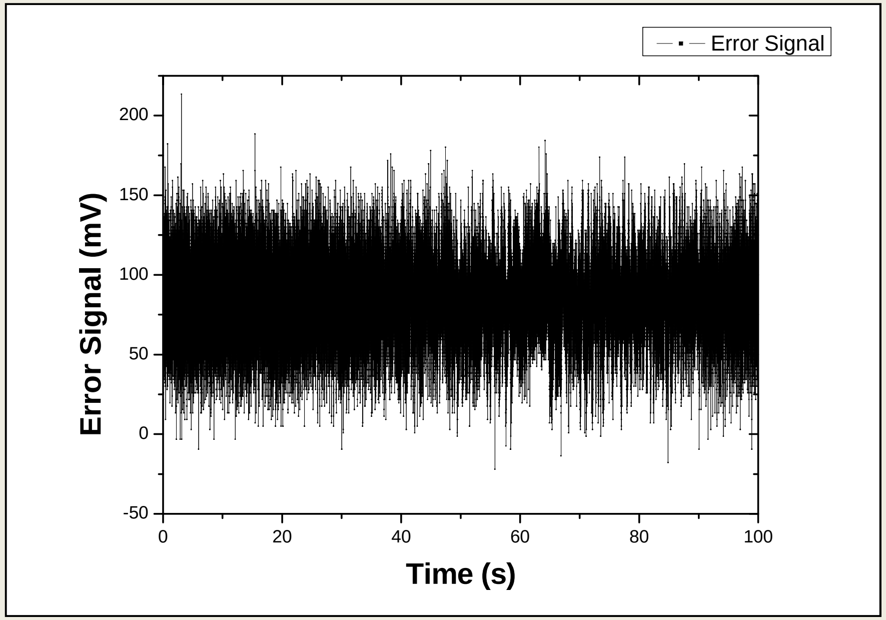
f_{EOM} = 15 MHz

Frequency stabilization of NPRO



Stabilized error signal

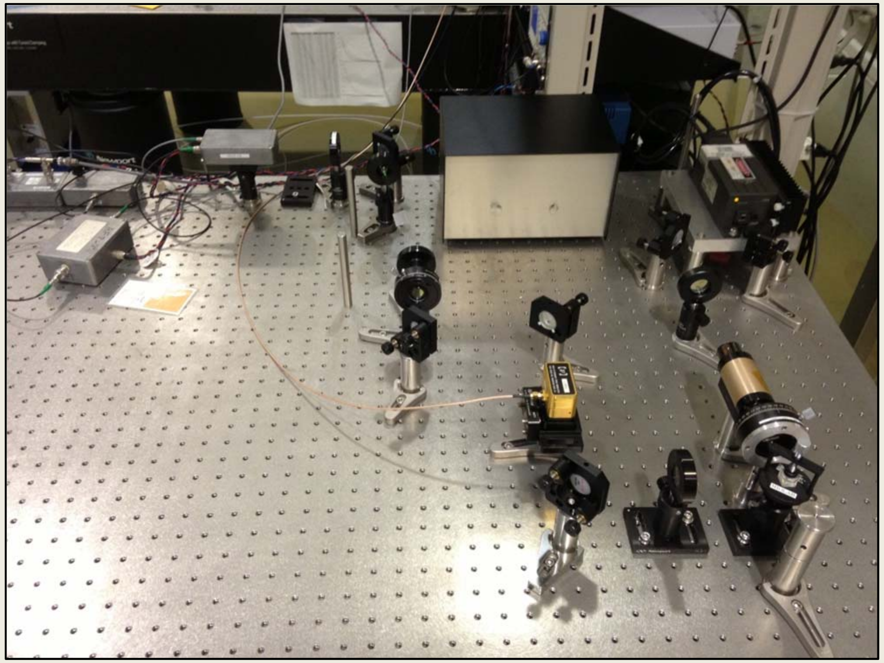


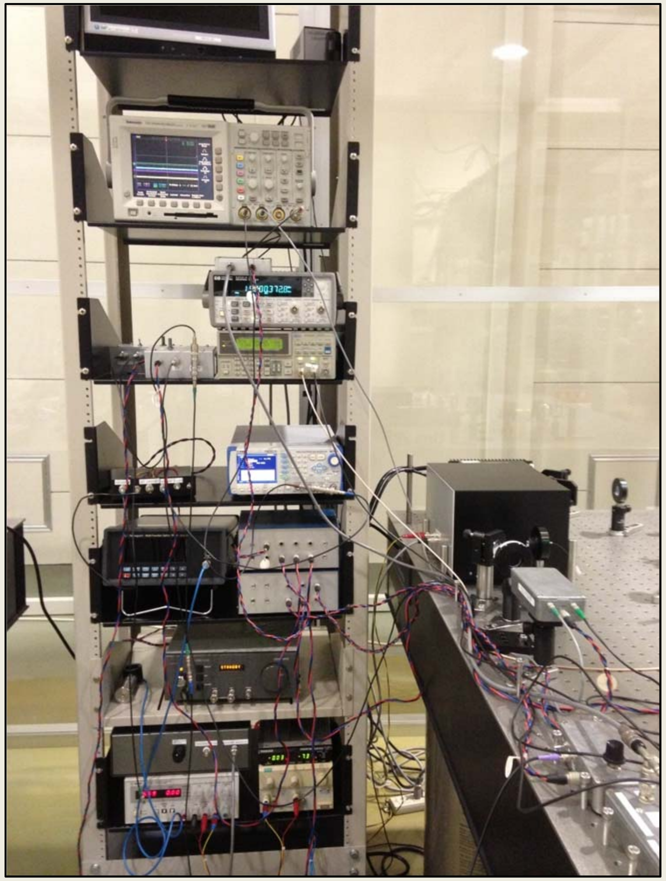


160 Hz with 1 Hz LPF

5.4 kHz without LPF

Experiment setup, see the size





Currently

- Start to build second FRC with a smaller coupling ratio of $\kappa = 10^{-5}$

- Will compare long-term frequency stability of two systems by using an AOM

- Hopefully, these FRC can be used for laser frequency stabilization of KAGRA lasers, e.g., master NPRO, etc.