

ERATO



MINOSHIMA
IOS
PROJECT



17/November/2015
ERATO meeting

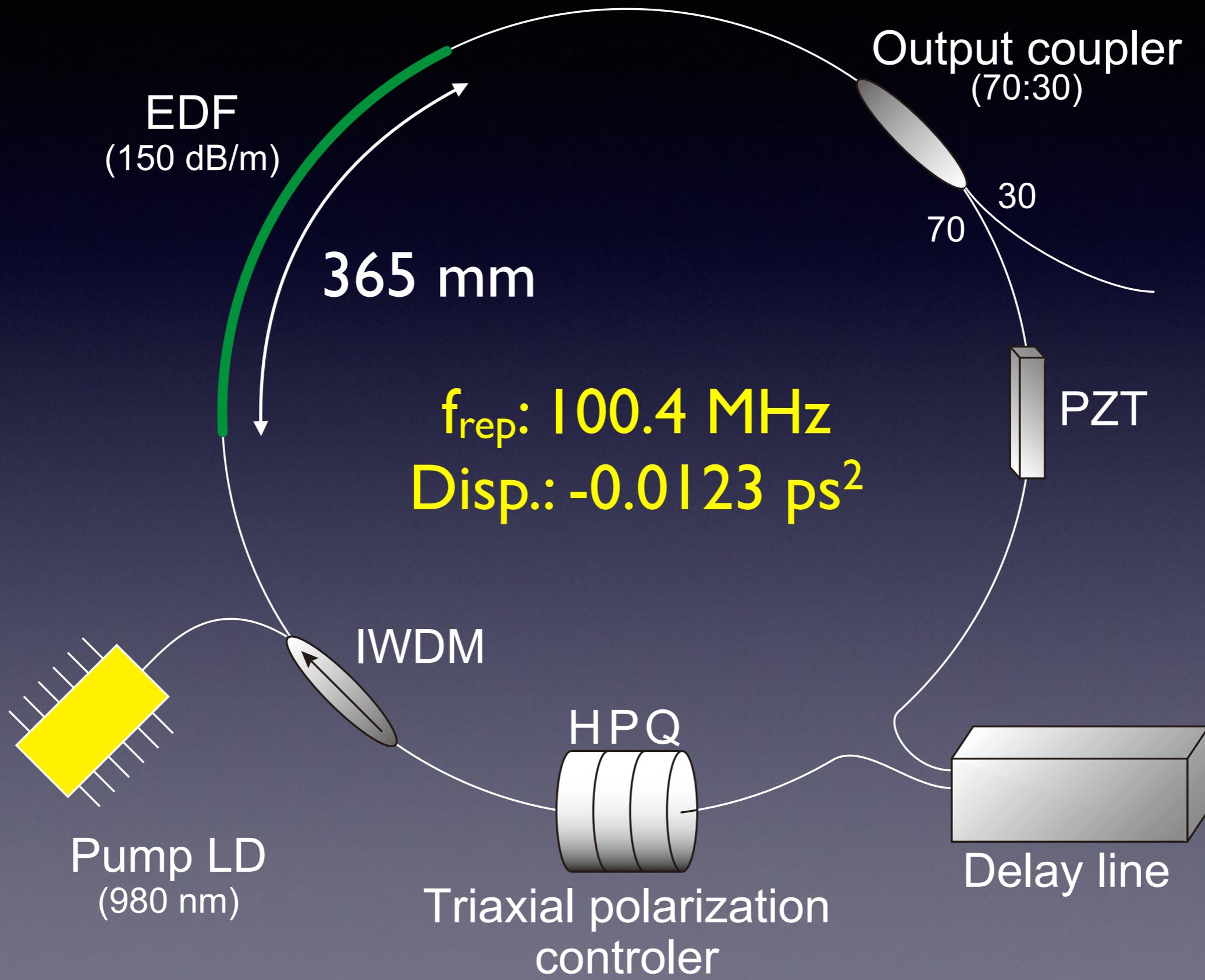
Development of Piezo-EOM dual-comb system

Takeo Minamikawa

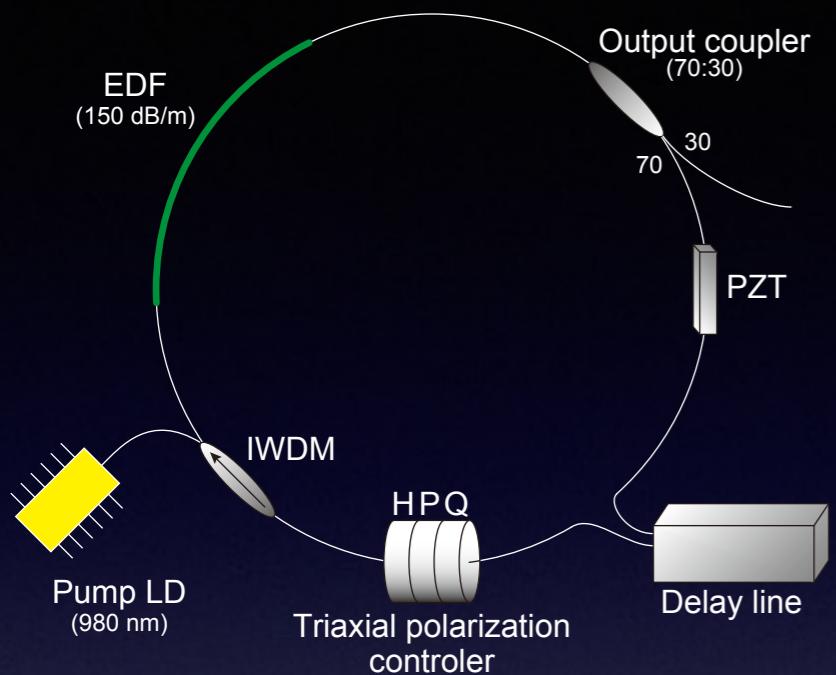
Institute of Technology and Science, Tokushima Univ.
JST/ERATO Minoshima Intelligent Optical Synthesizer Project

Contact: minamikawa.takeo@tokushima-u.ac.jp

Fiber laser setup

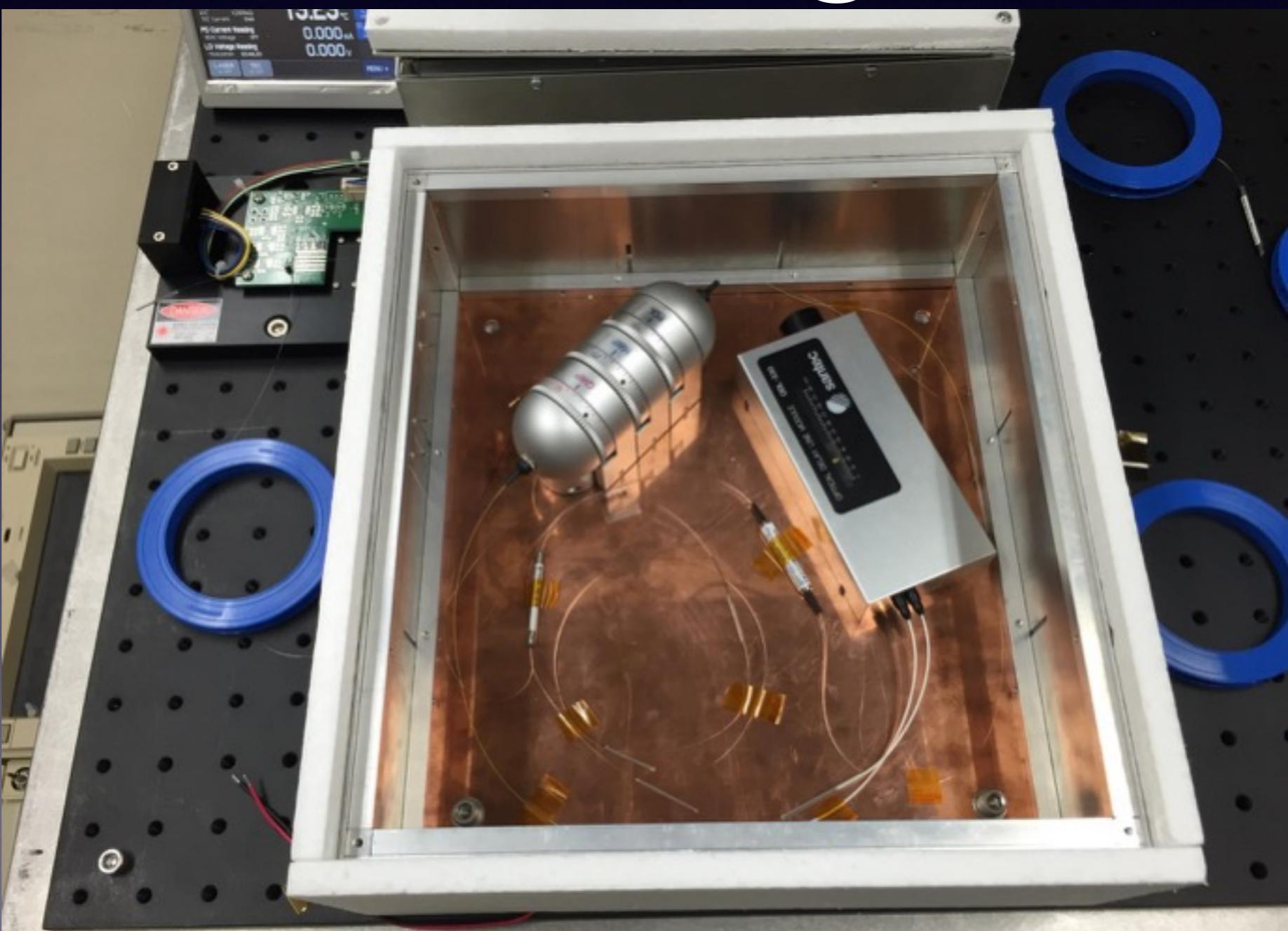


Fiber laser setup in chamber

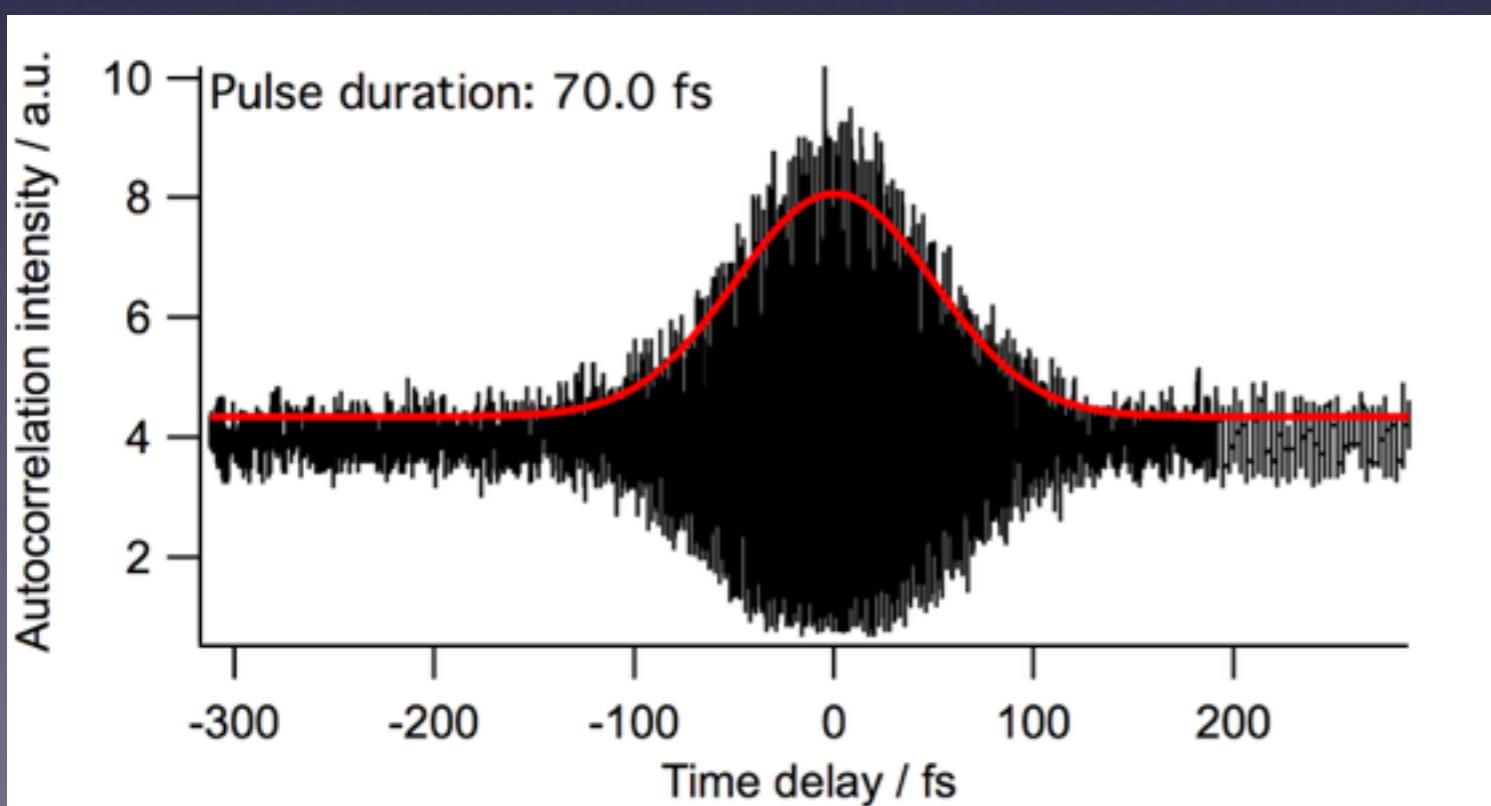
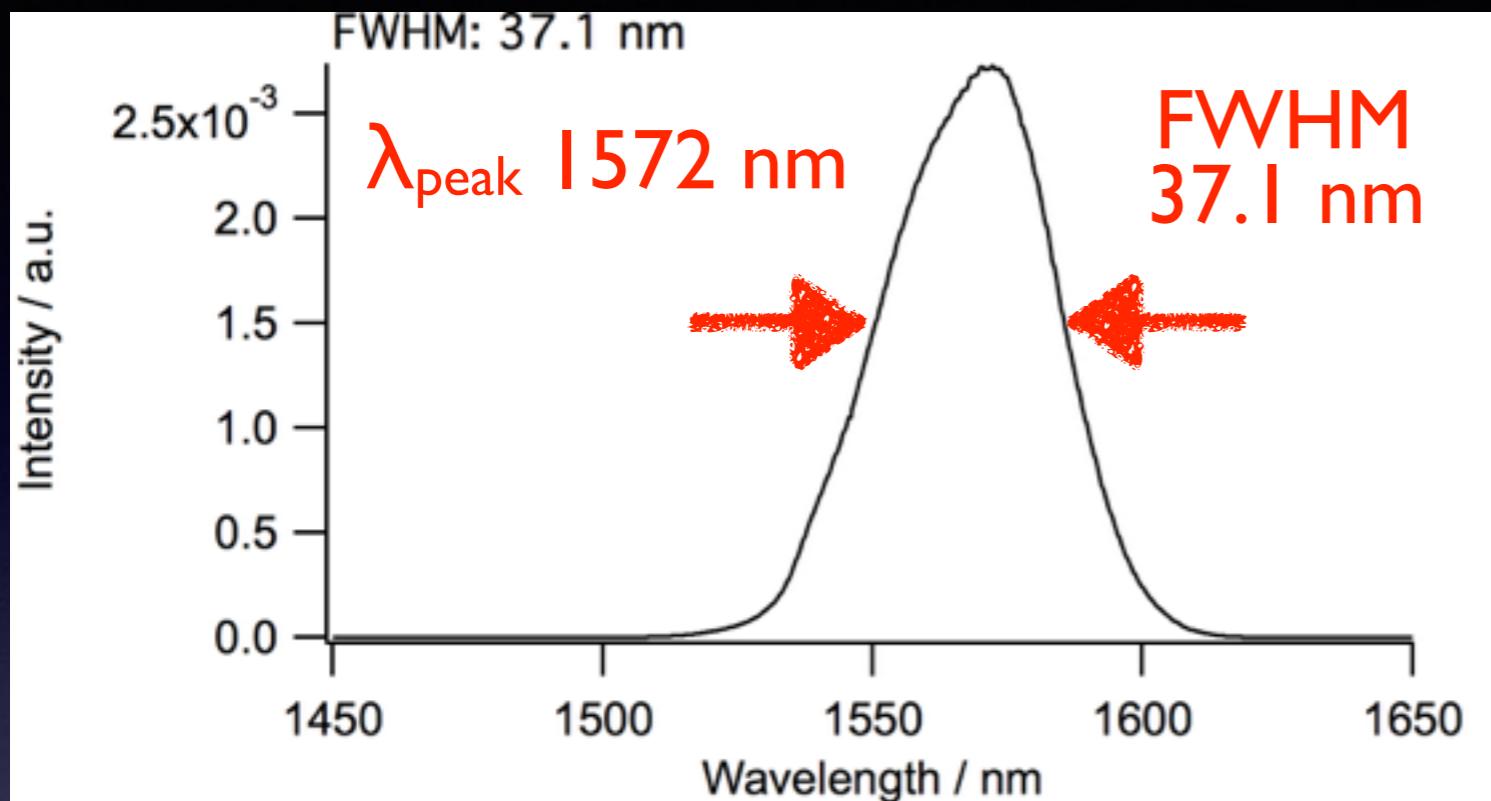


Laser power
9.49 mW

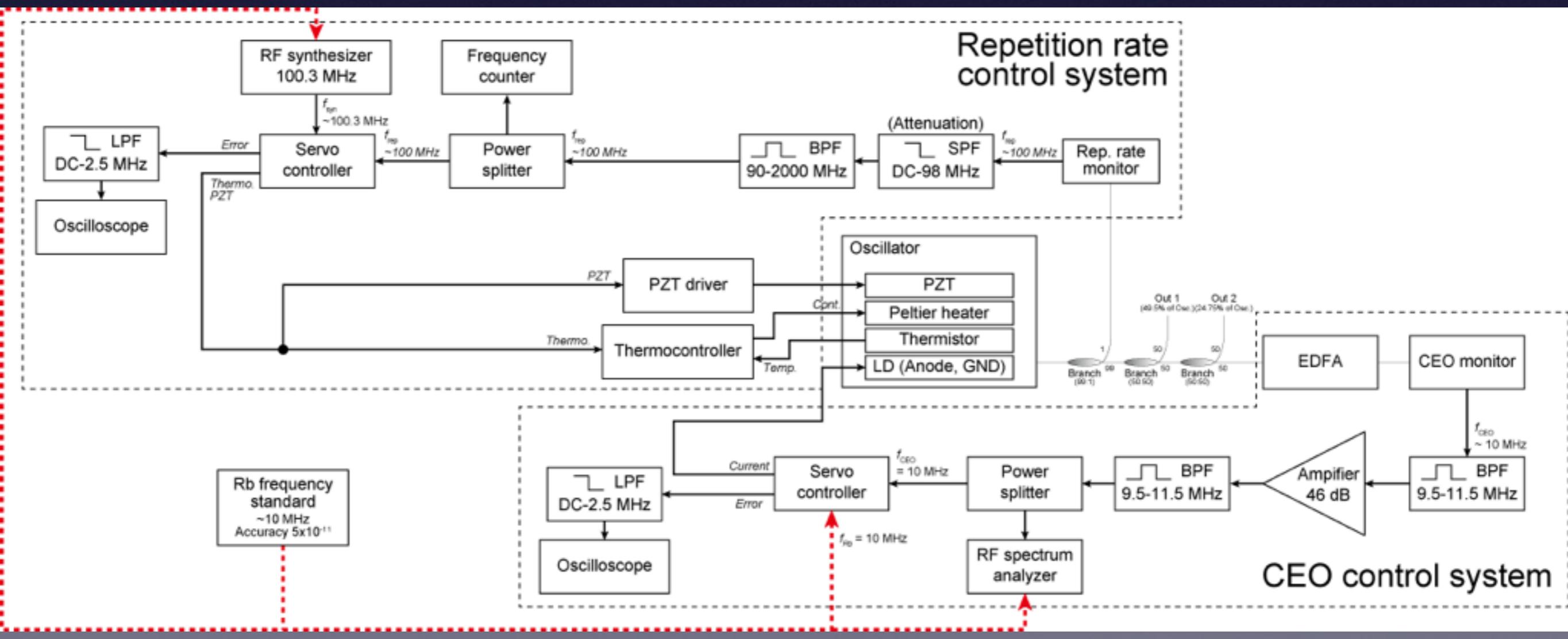
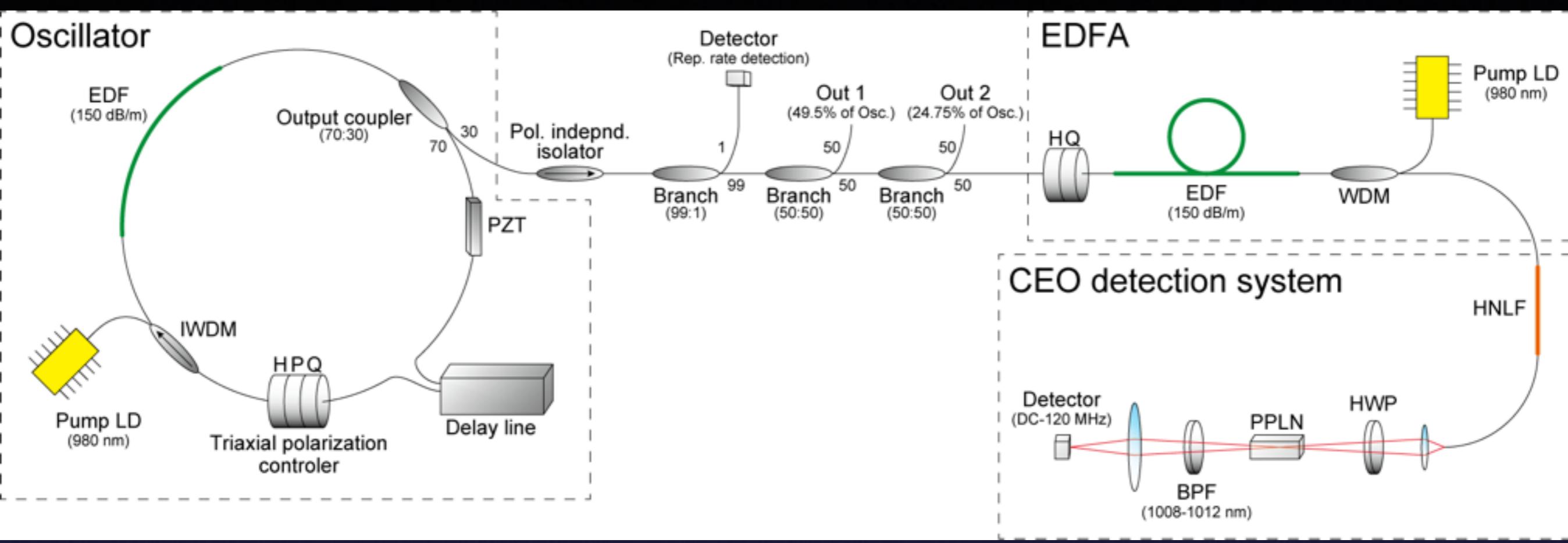
LD current: 360 mA @ 21.0 °C

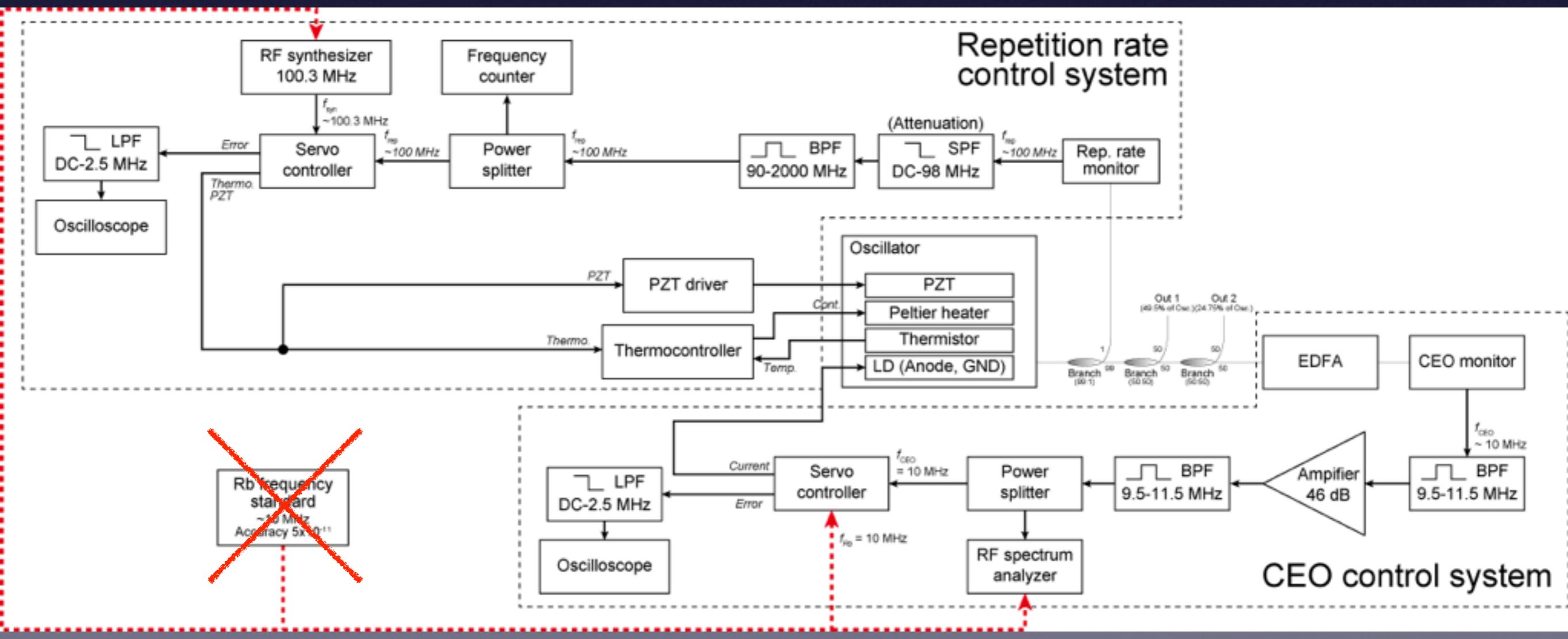
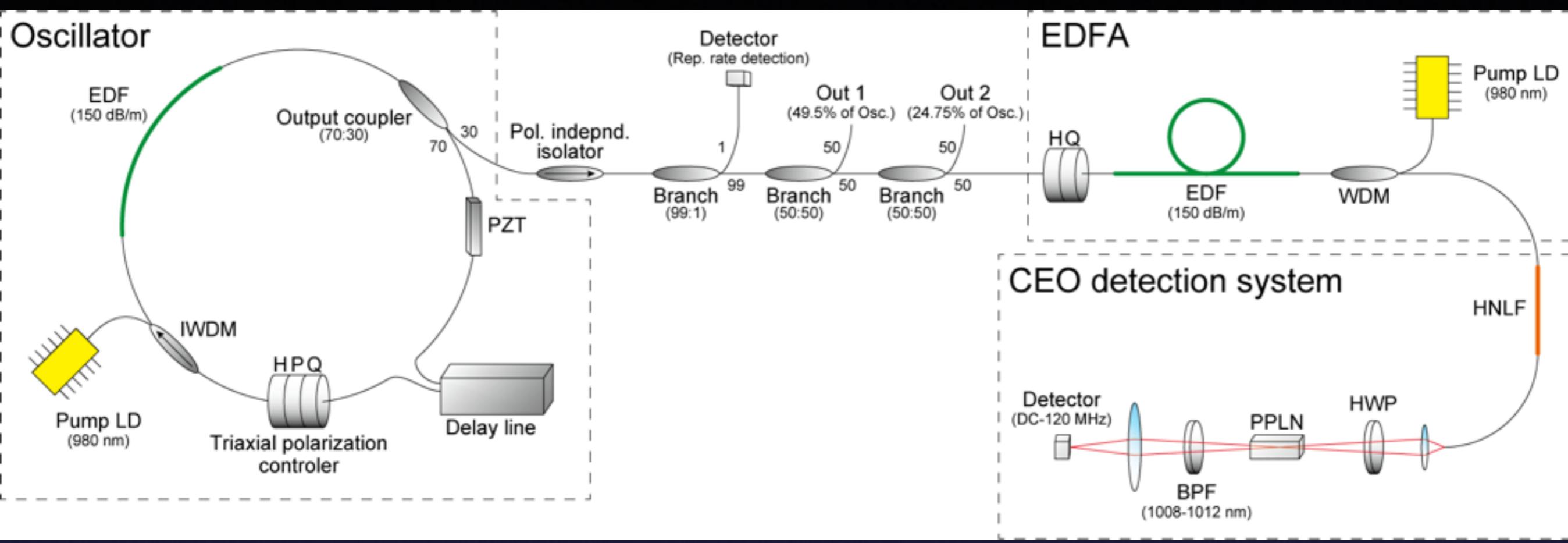


Fiber laser spec. - Wavelength -



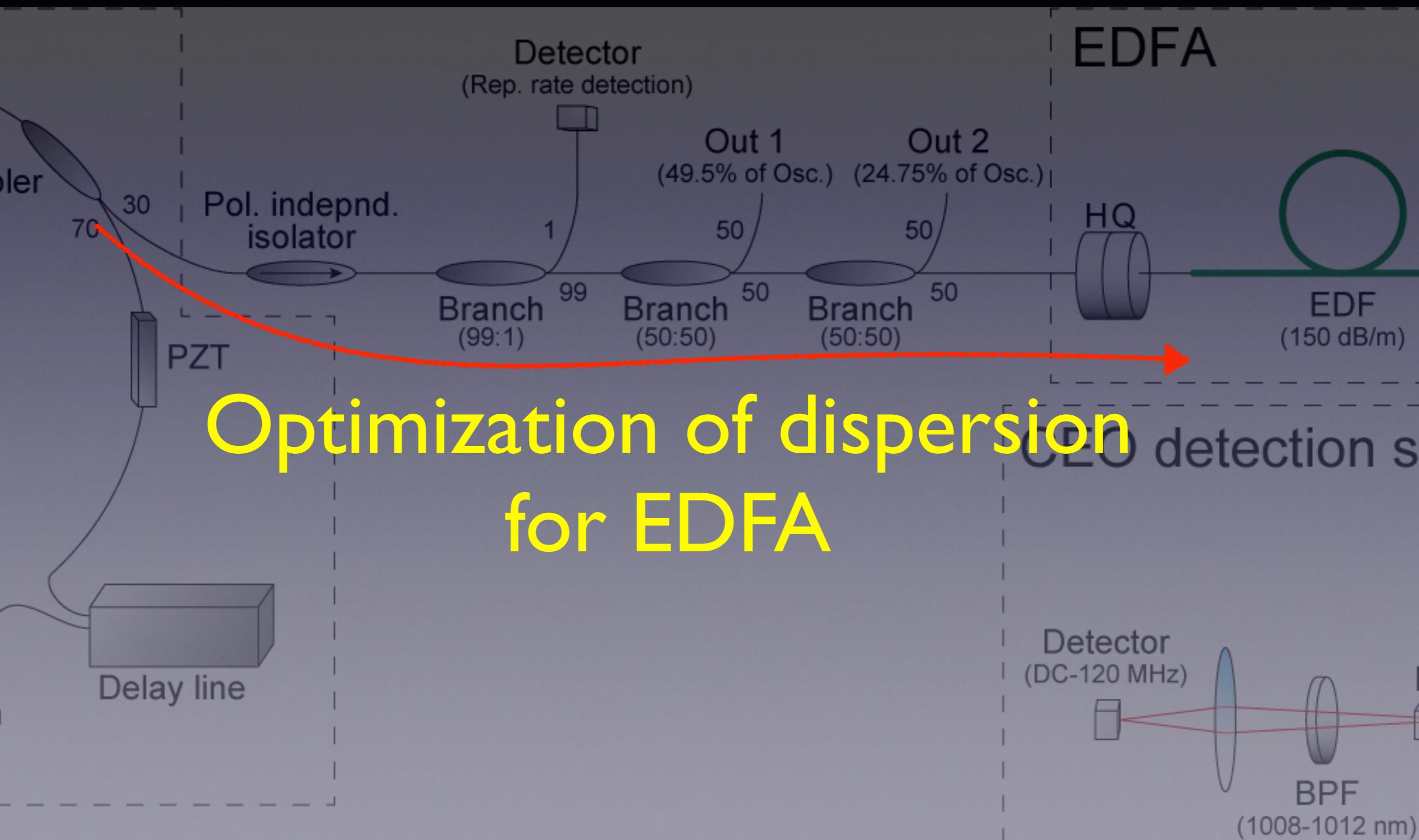
Progress



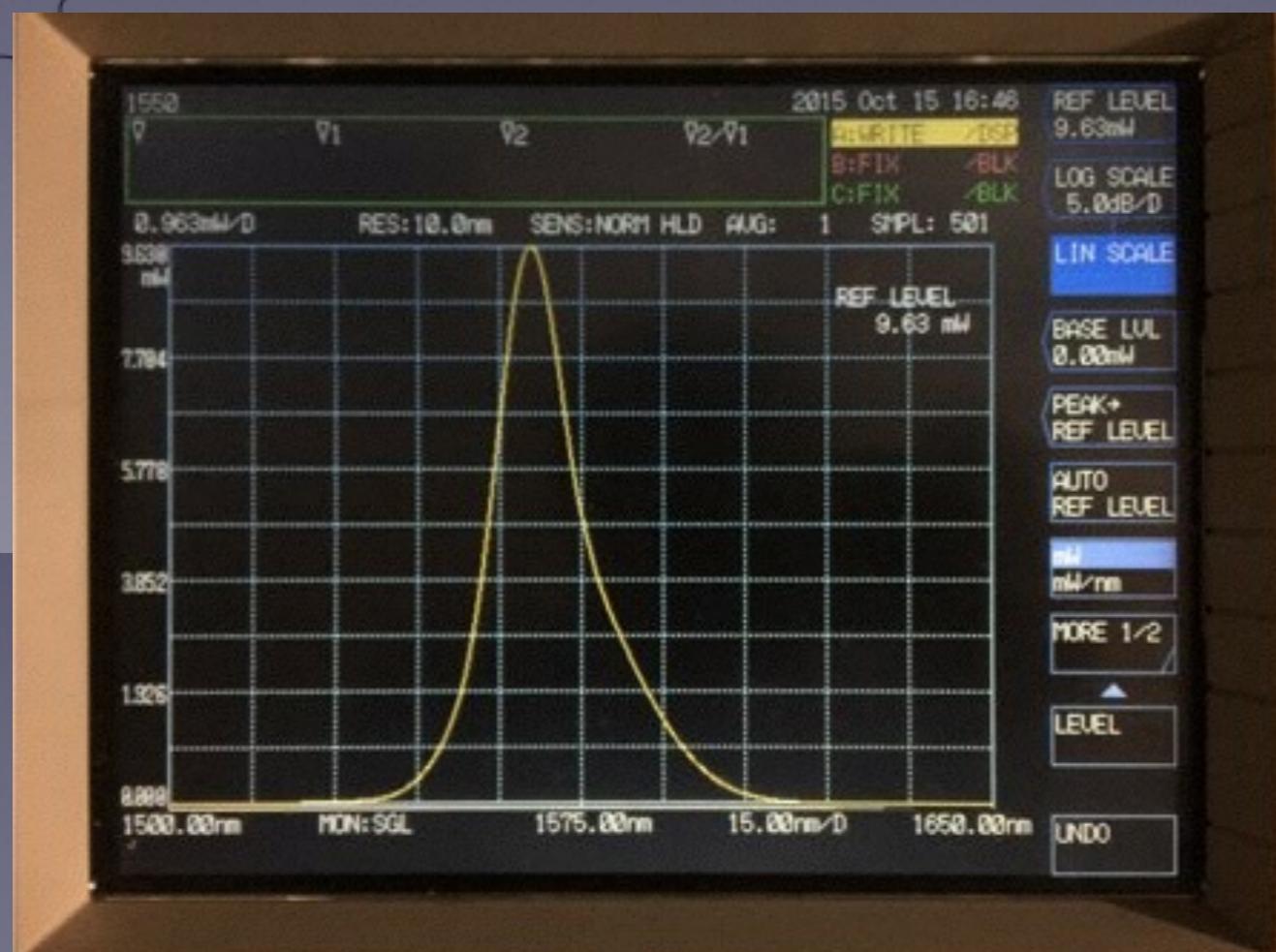
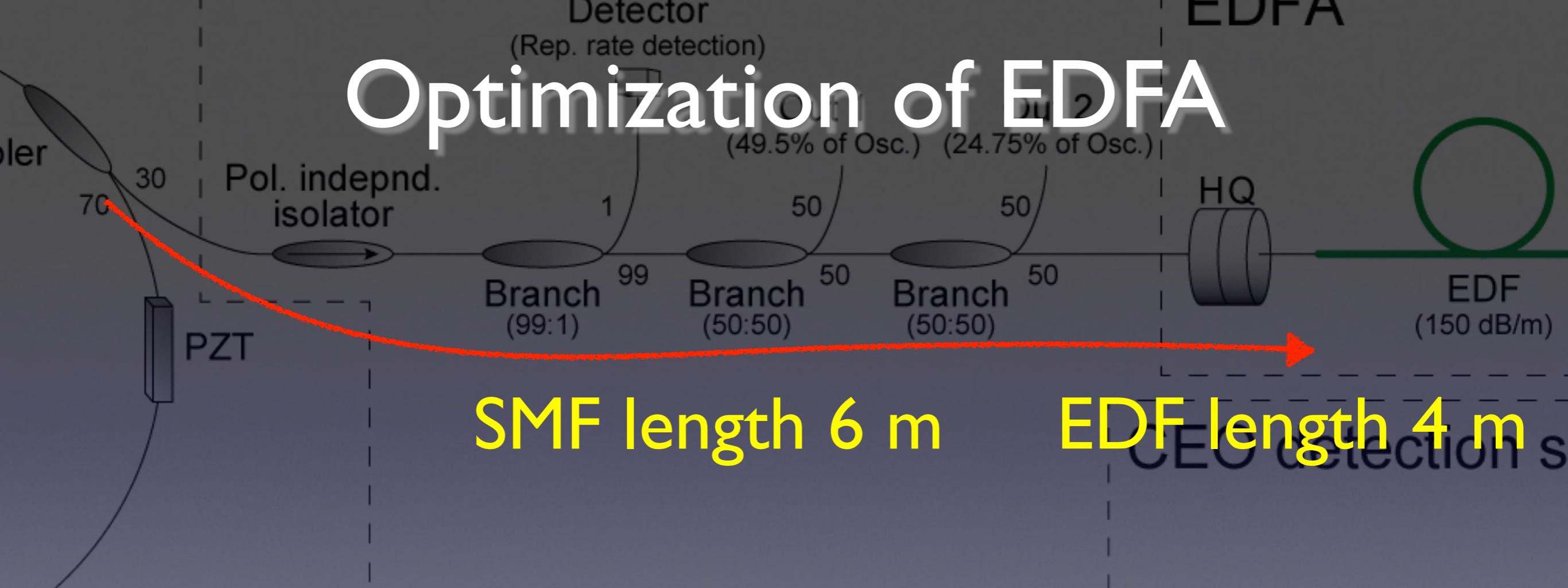


f_{CEO} stabilization

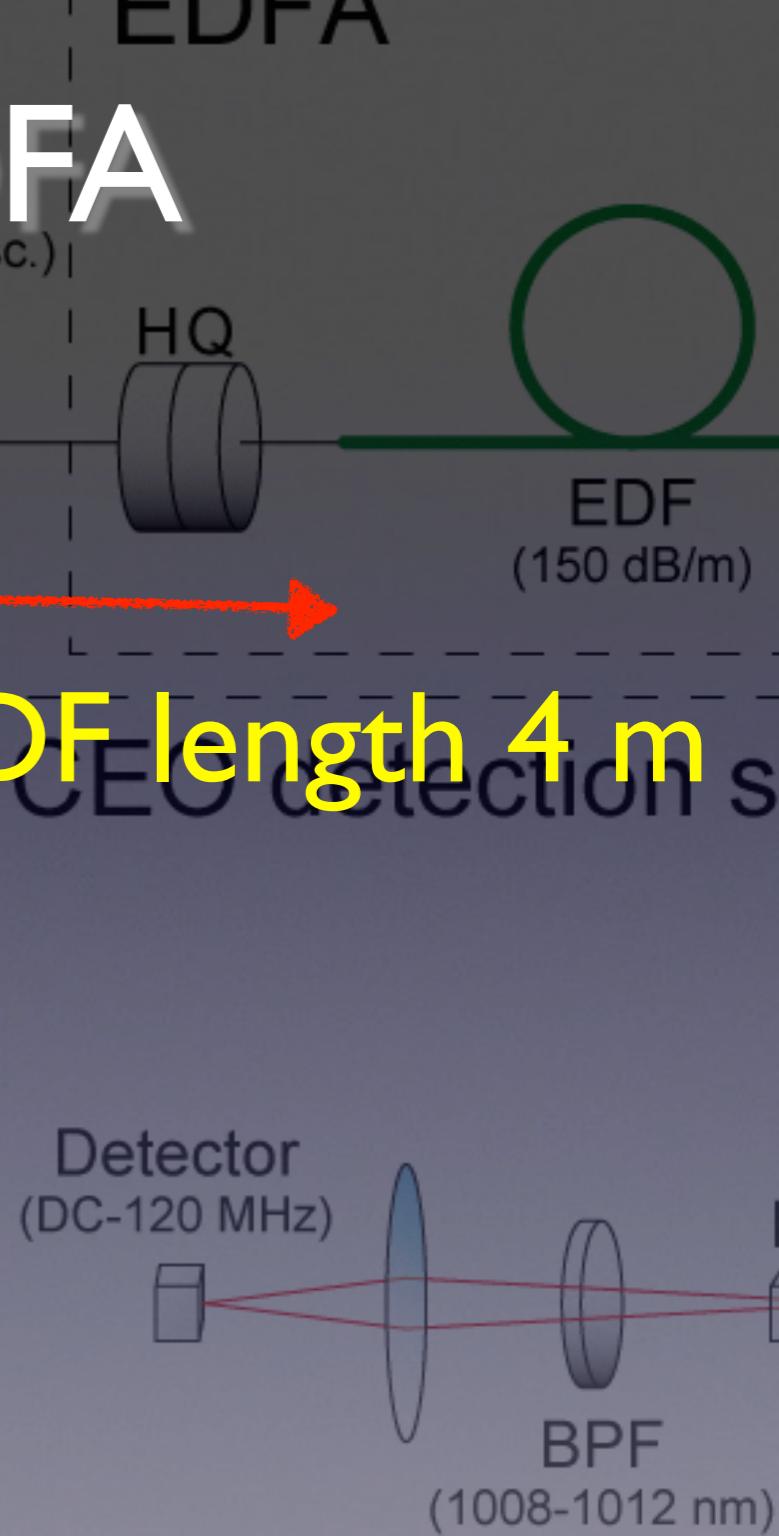
Optimization of EDFA



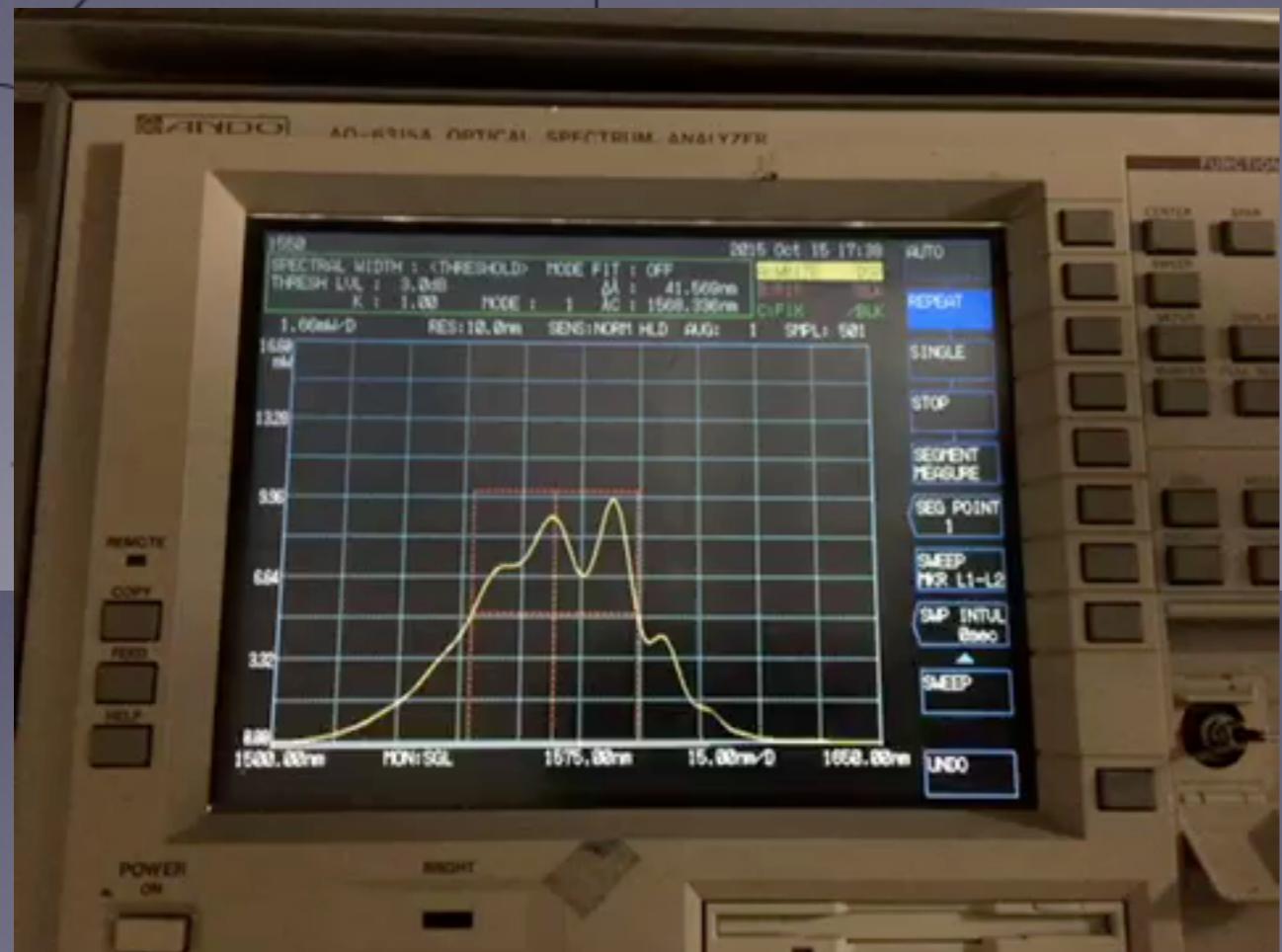
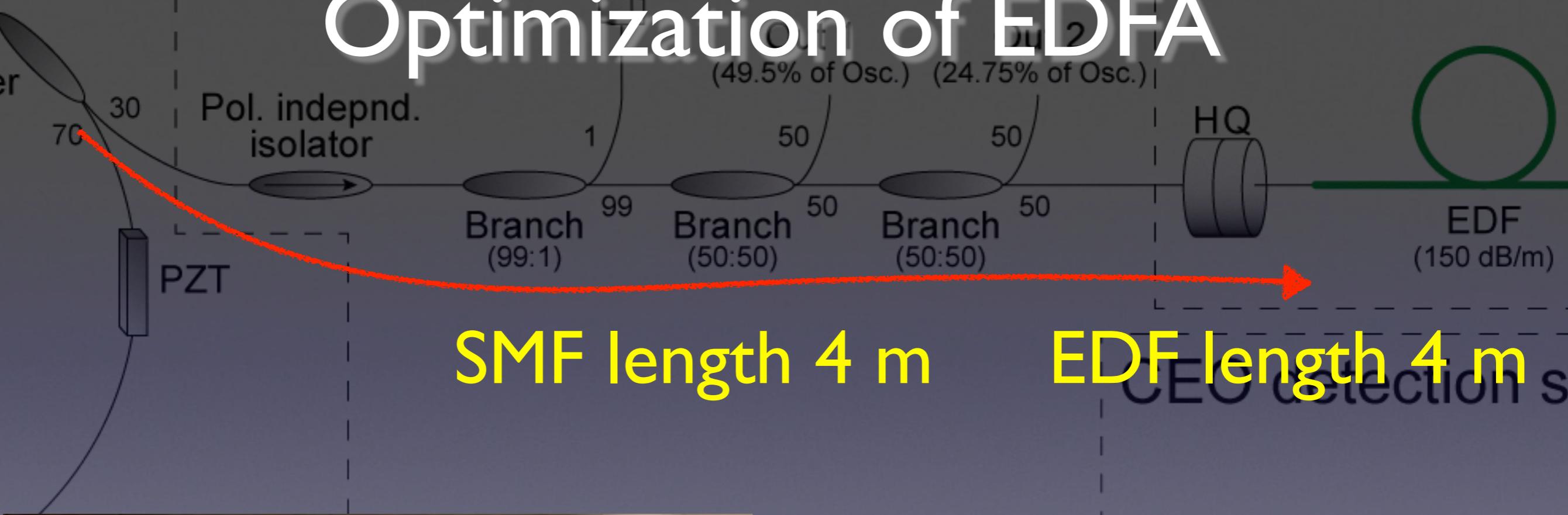
Optimization of EDFA



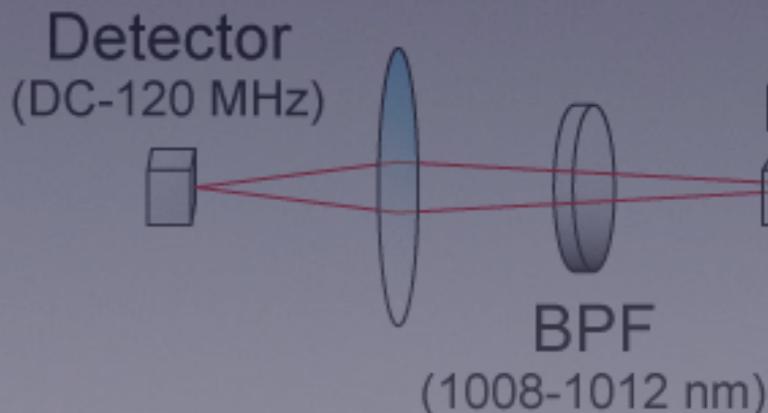
No change
by tuning HWP and QWP



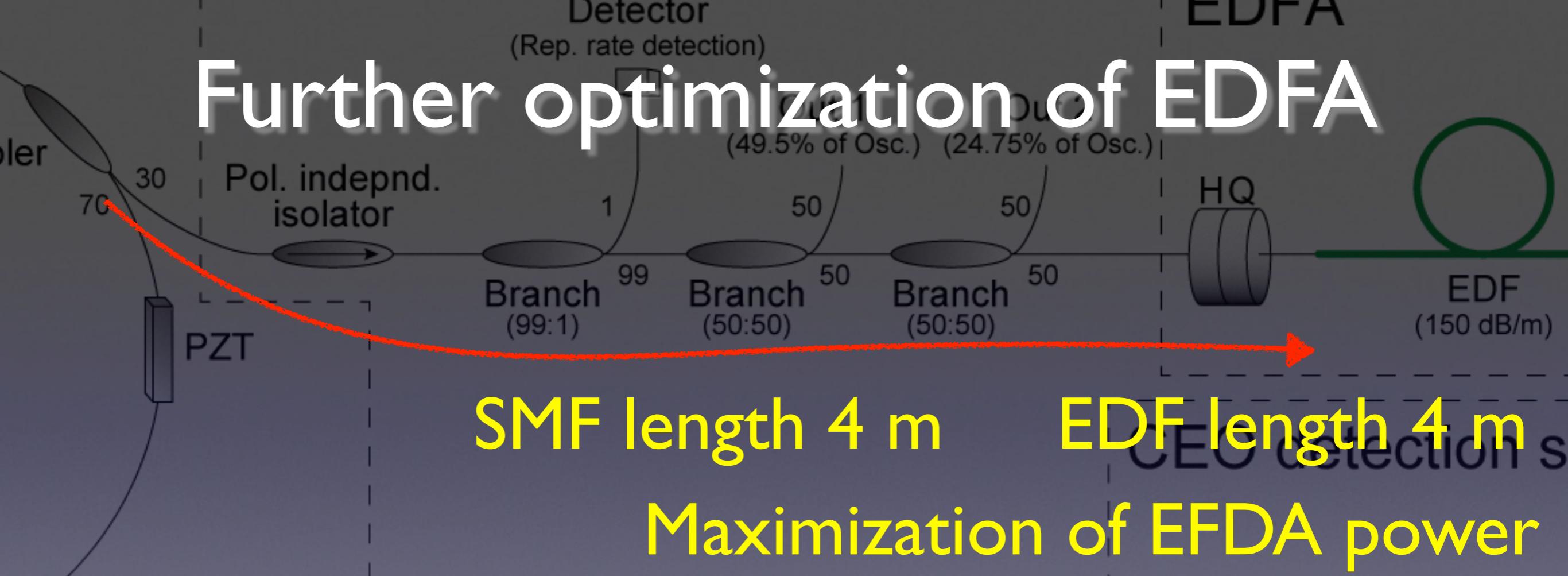
Optimization of EDFA



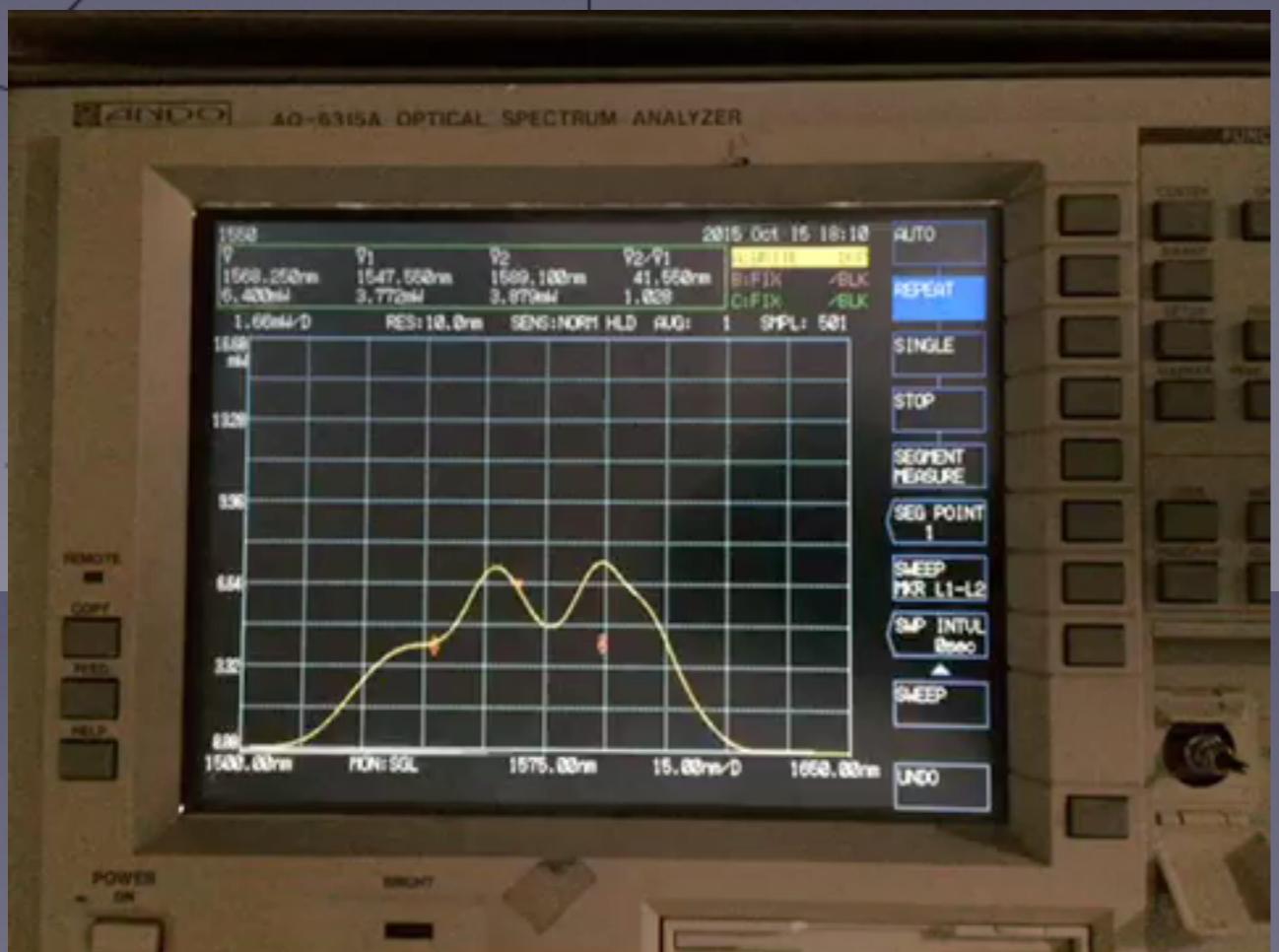
Changed
by tuning HWP and QWP



Further optimization of EDFA



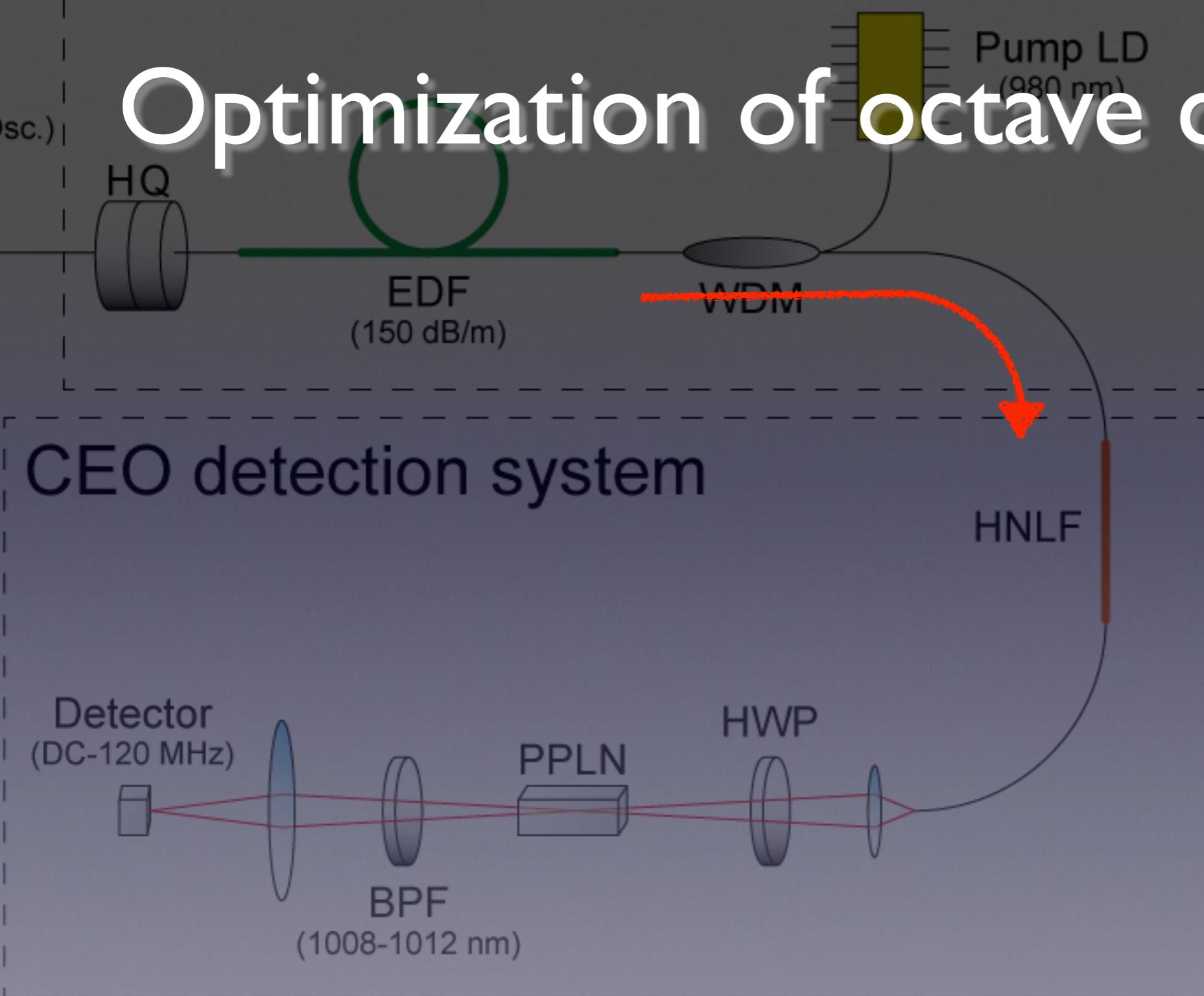
Maximization of EDFA power



Output power of EDFA
Initial 51.0 mW
10 cm shorter 53.5 mW
10 cm shorter 54.5 mW
10 cm shorter 55.0 mW
10 cm shorter 55.0 mW

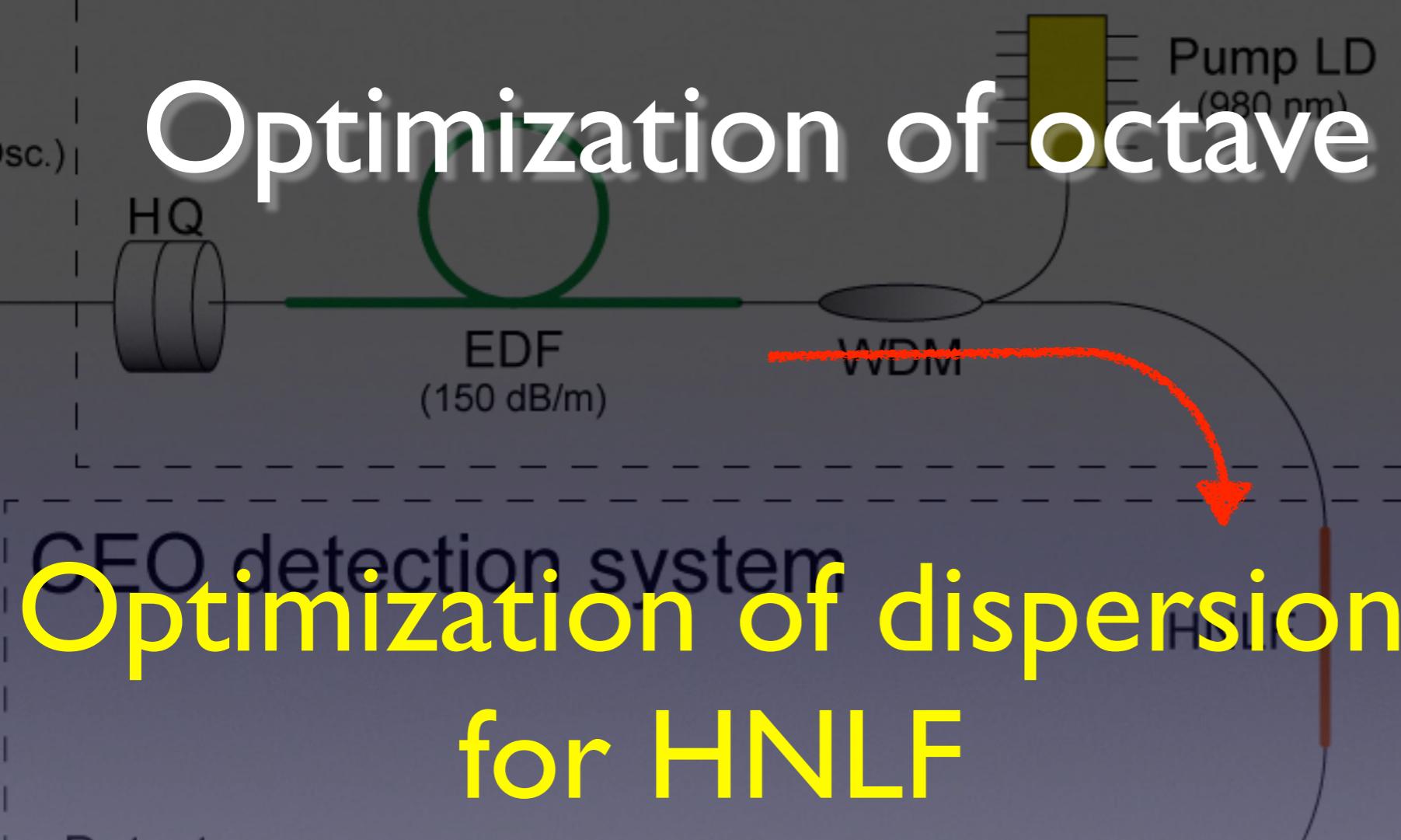
@LD 800 mA

Optimization of octave continuum



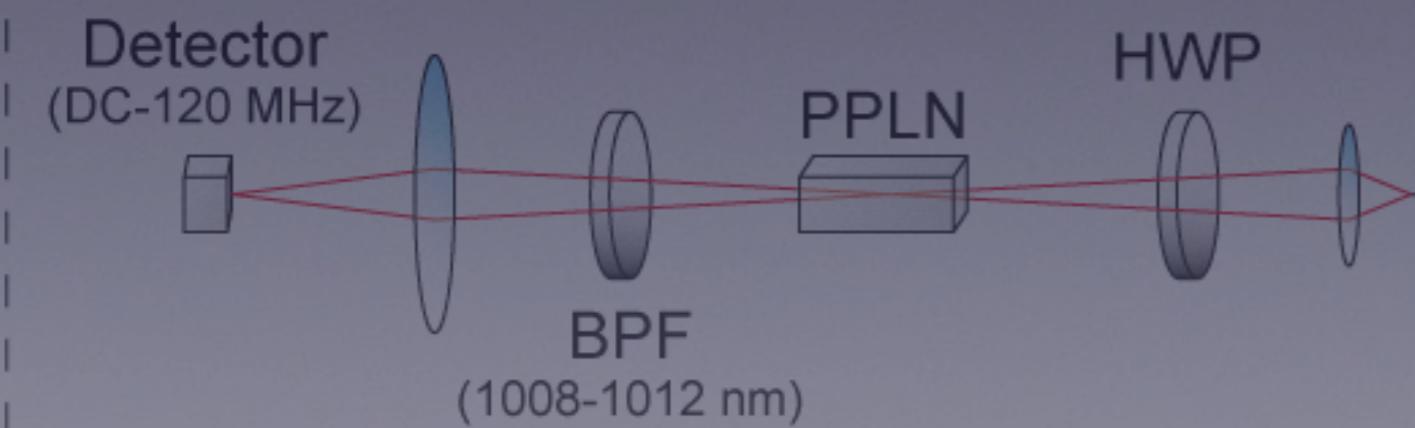
Optimization of dispersion
for HNLF

Optimization of octave continuum

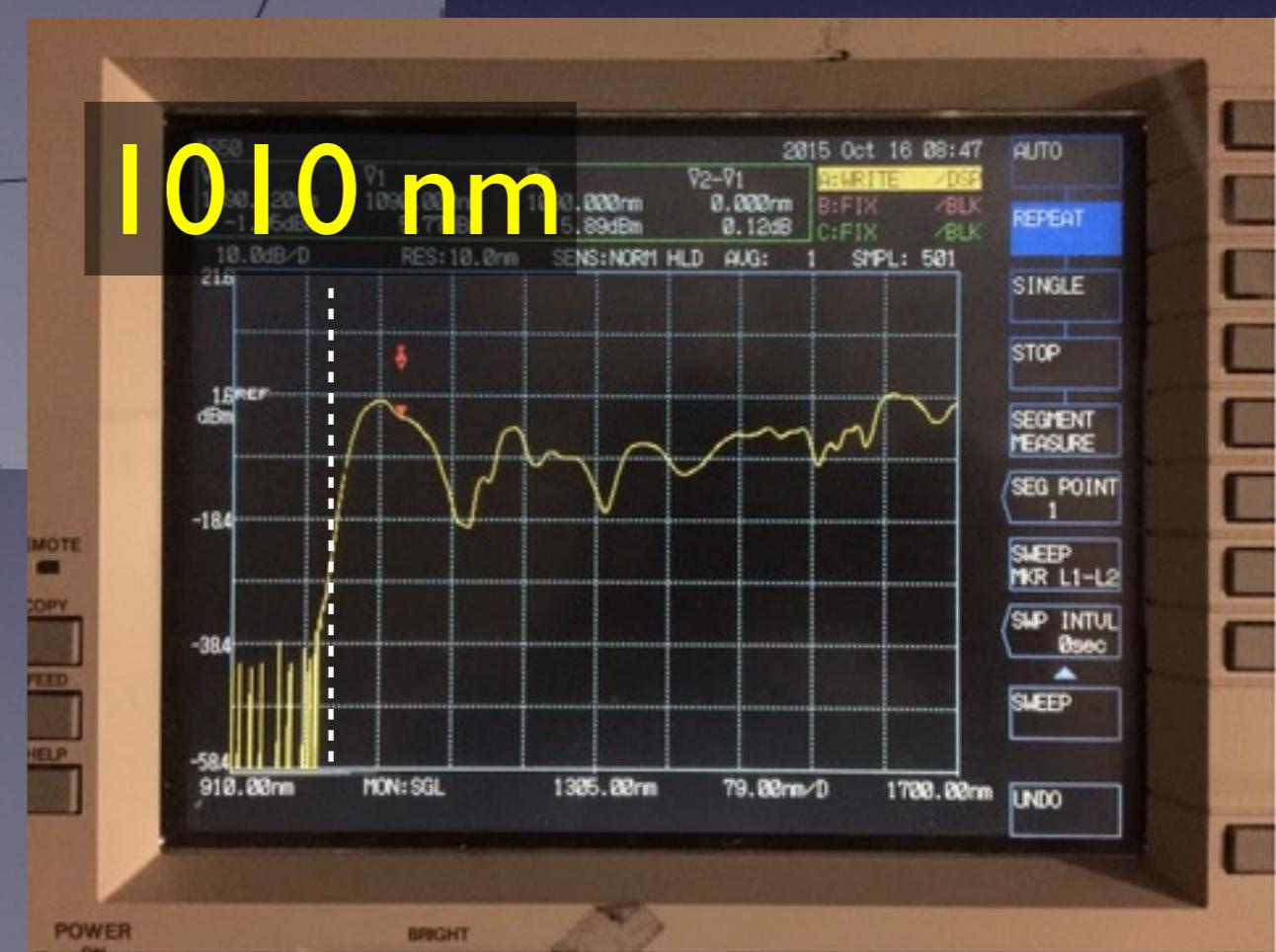


HNLF length
20 cm

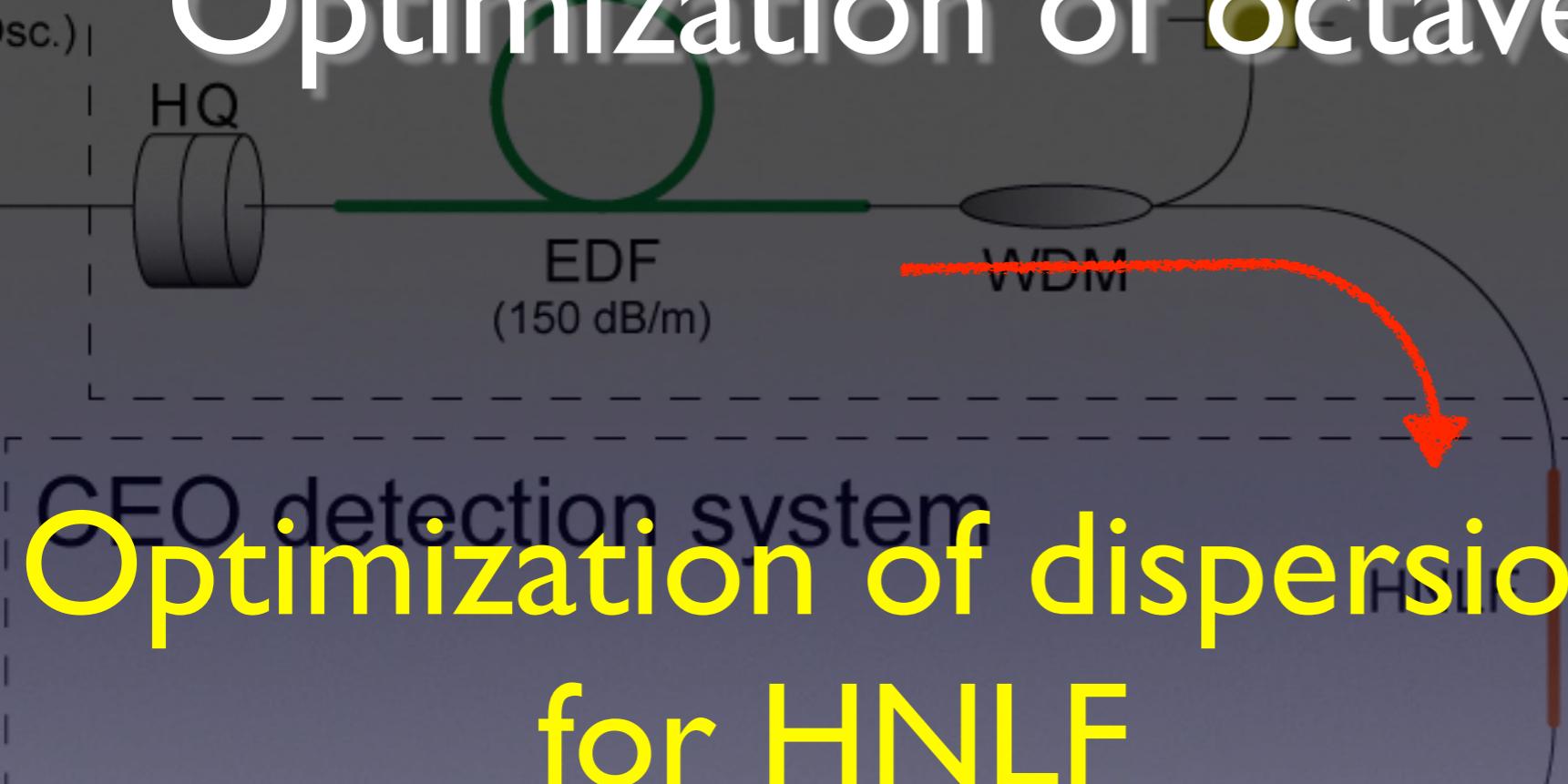
Optimization of dispersion for HNLF



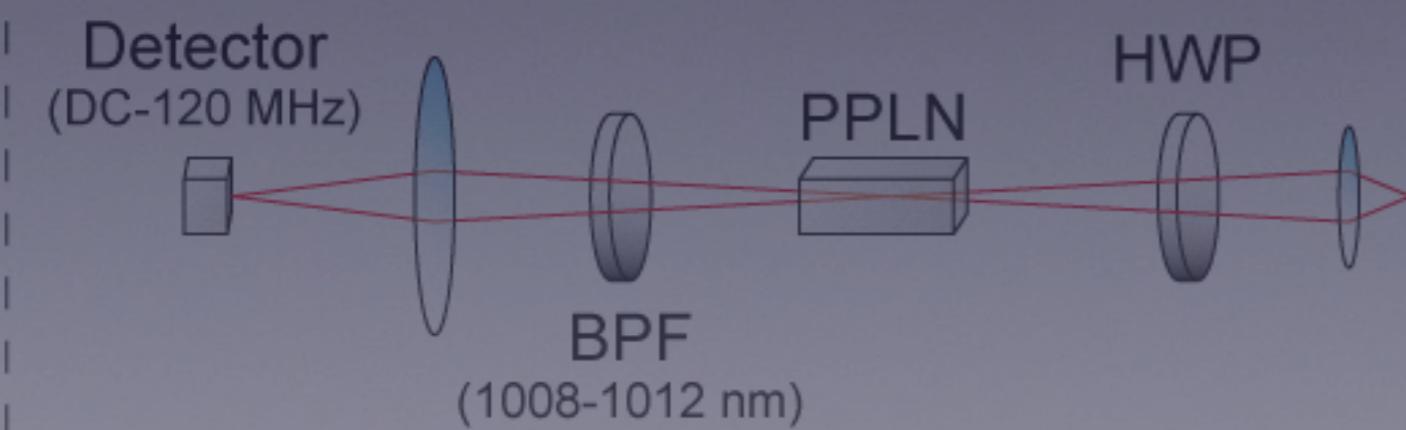
Initial
SMF length 2.4 m
(WDM 40 cm)



Optimization of octave continuum

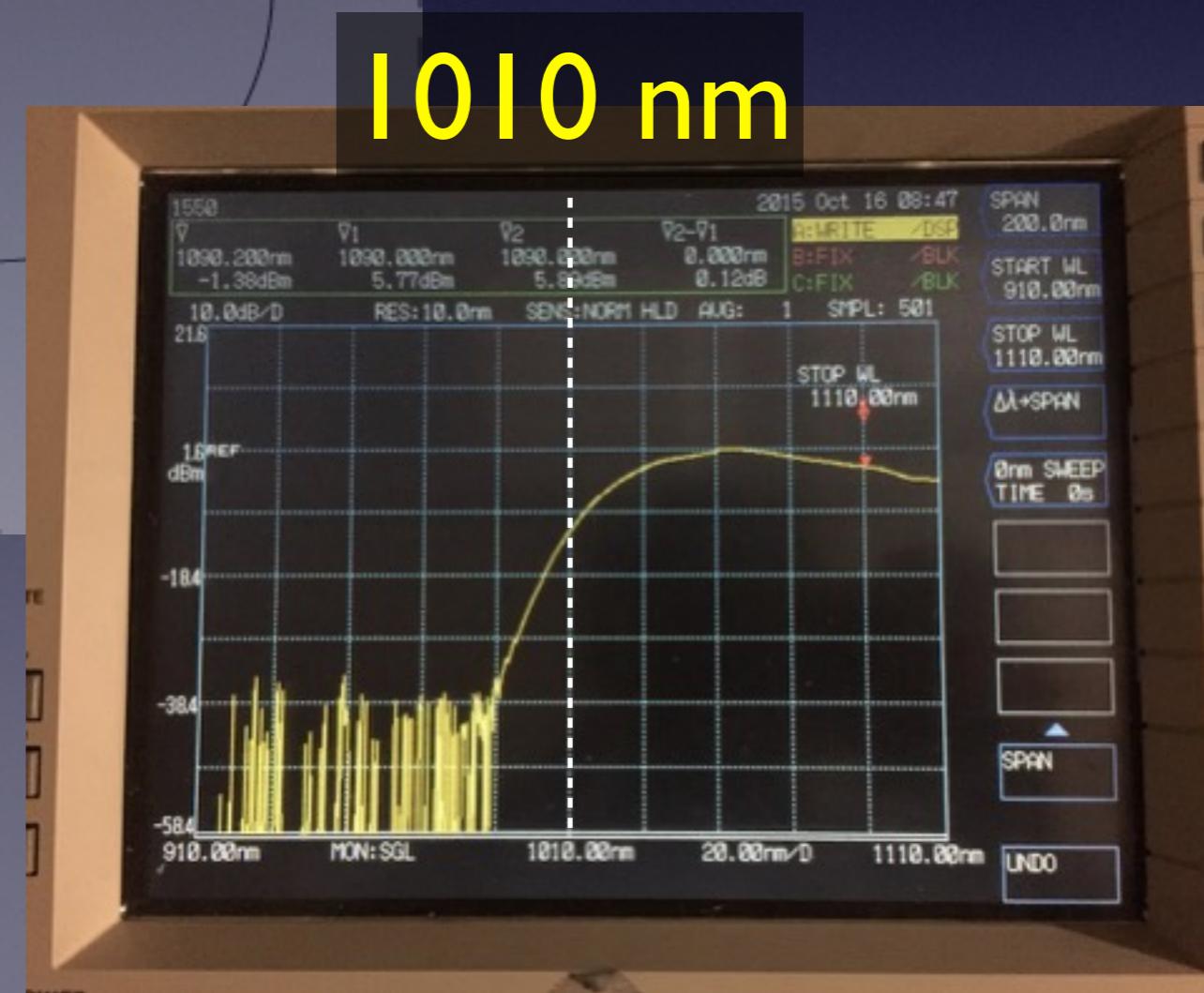


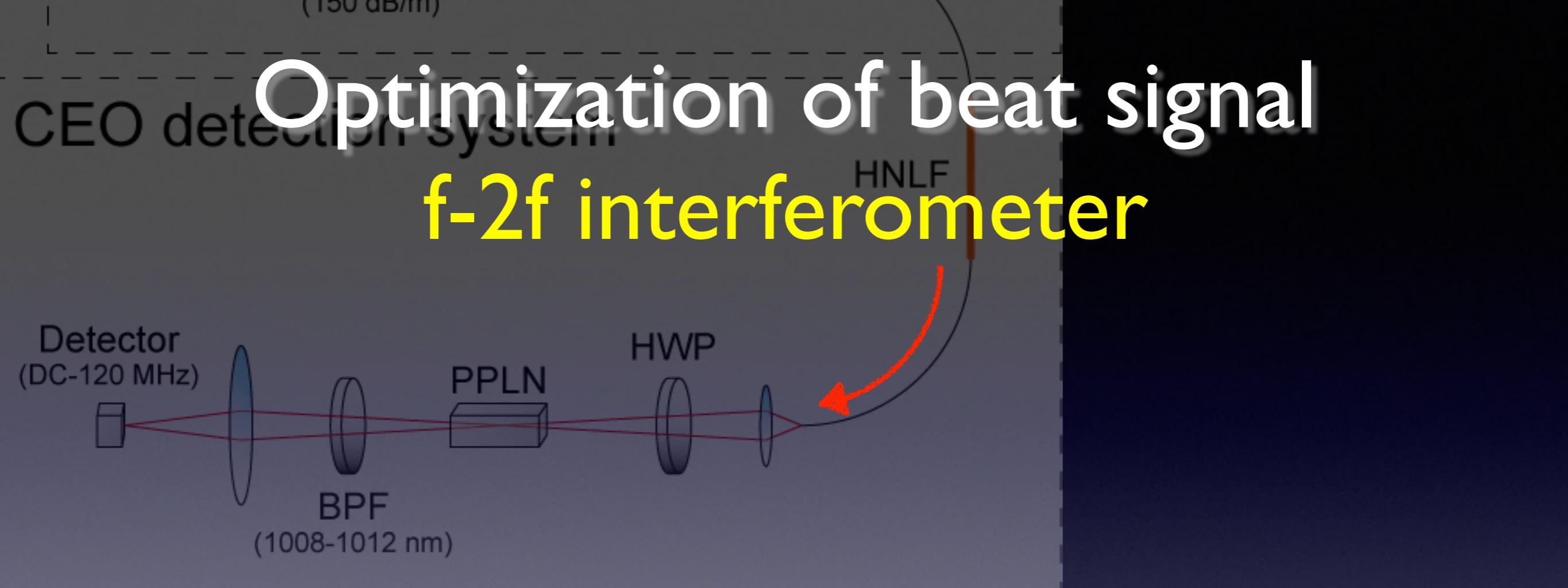
Optimization of dispersion for HNLF



Maximize spectral intensity at 1010 nm

Optimized
SMF length 30 cm

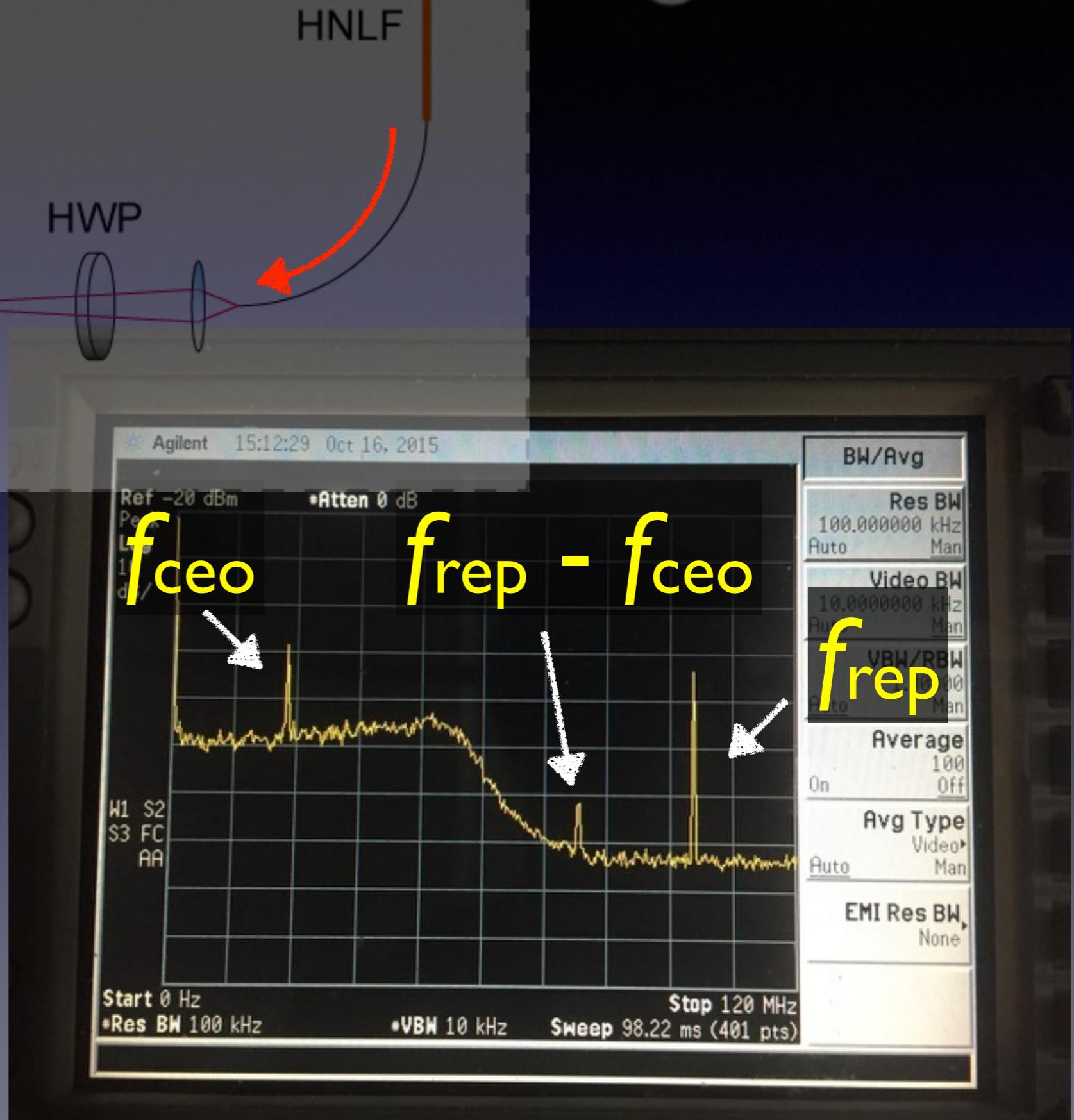




Optimization of dispersion for beat signal (1010 nm and SHG of 2020 nm)

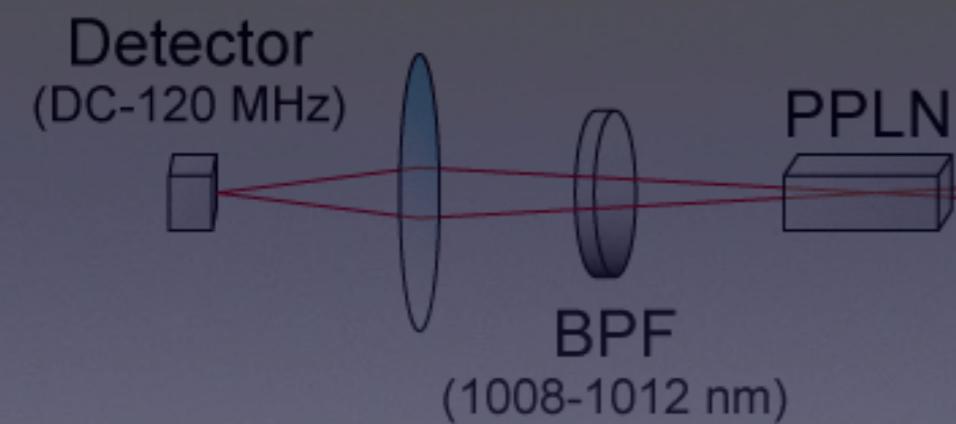
Optimization of beat signal

w/ SPF
(DC-48 MHz)

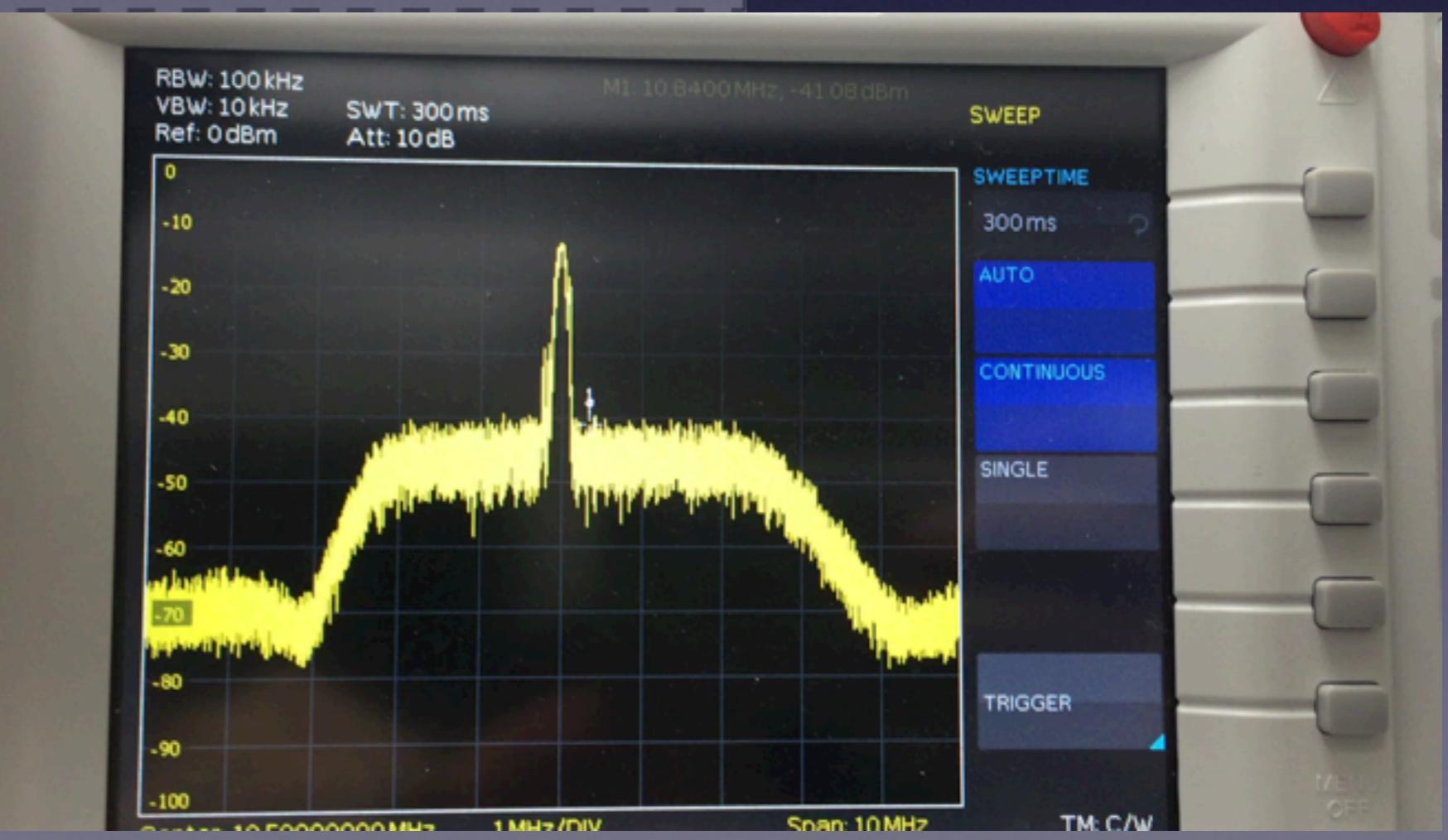


(150 dB/m)

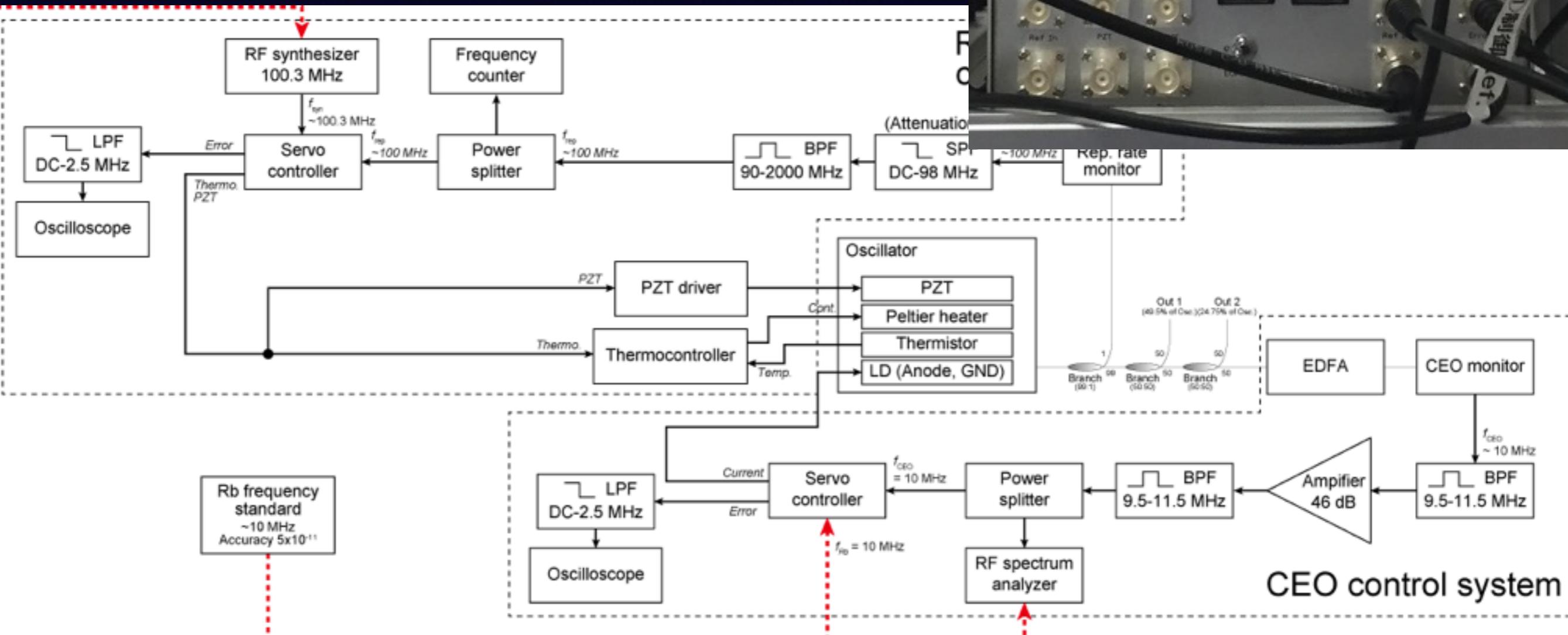
Optimization of beat signal



w/ BPF
(9.5-11.5 MHz)

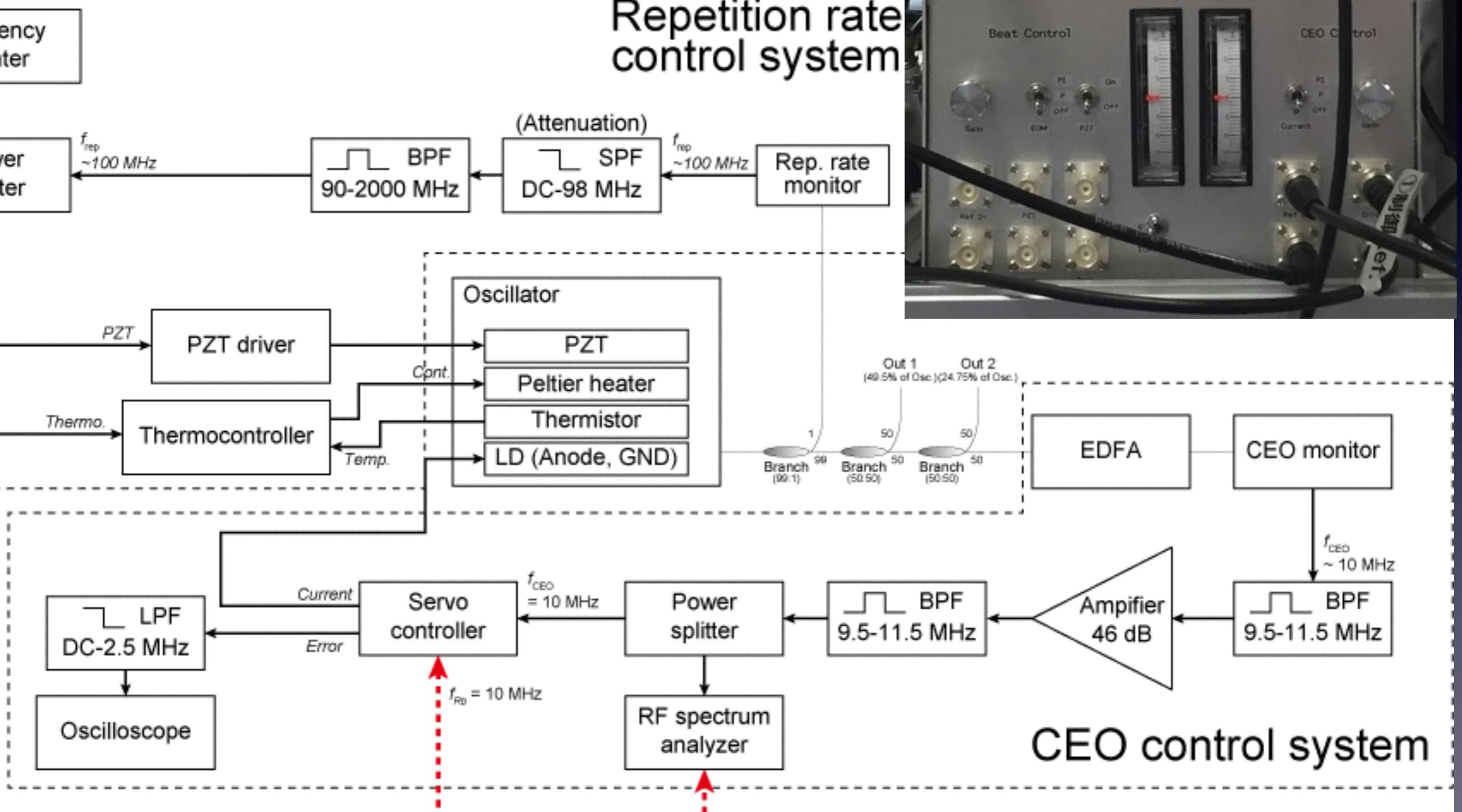


f_{CEO} stabilization



f_{CEO} stabilization

Repetition rate control system



f_{CEO} stabilization

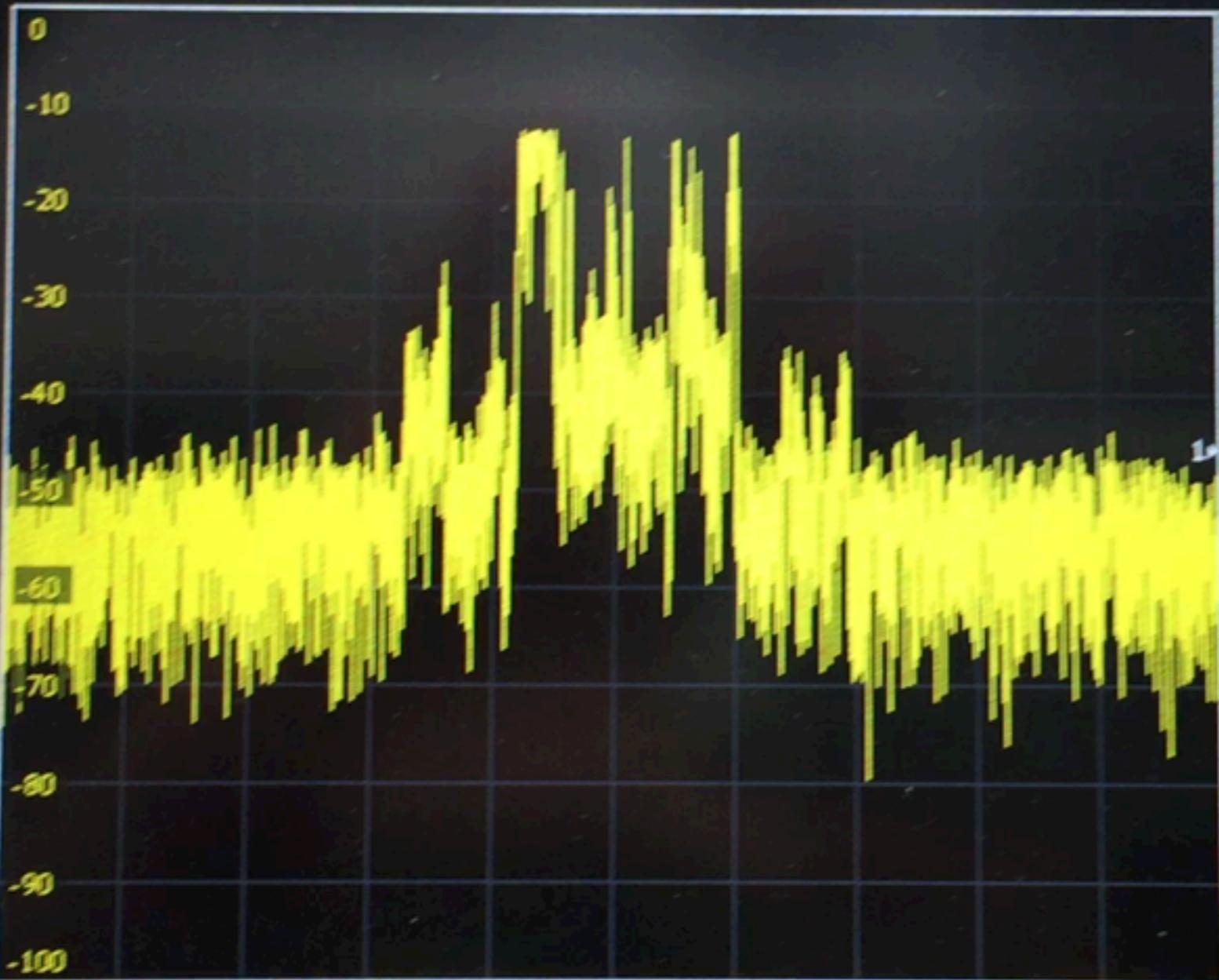
ROHDE & SCHWARZ
HAMEG

HMS-X SPECTRUM ANALYZER

RBW: 10 kHz
VBW: 10 kHz
Ref: 0 dBm

SWT: 180 ms
Att: 10 dB

M1: 10.80000 MHz, -47.46 dBm



BANDWIDTH

RBW
10 kHz

AUTO RBW

VBW
10 kHz

AUTO VBW

Center: 10.50000000 MHz

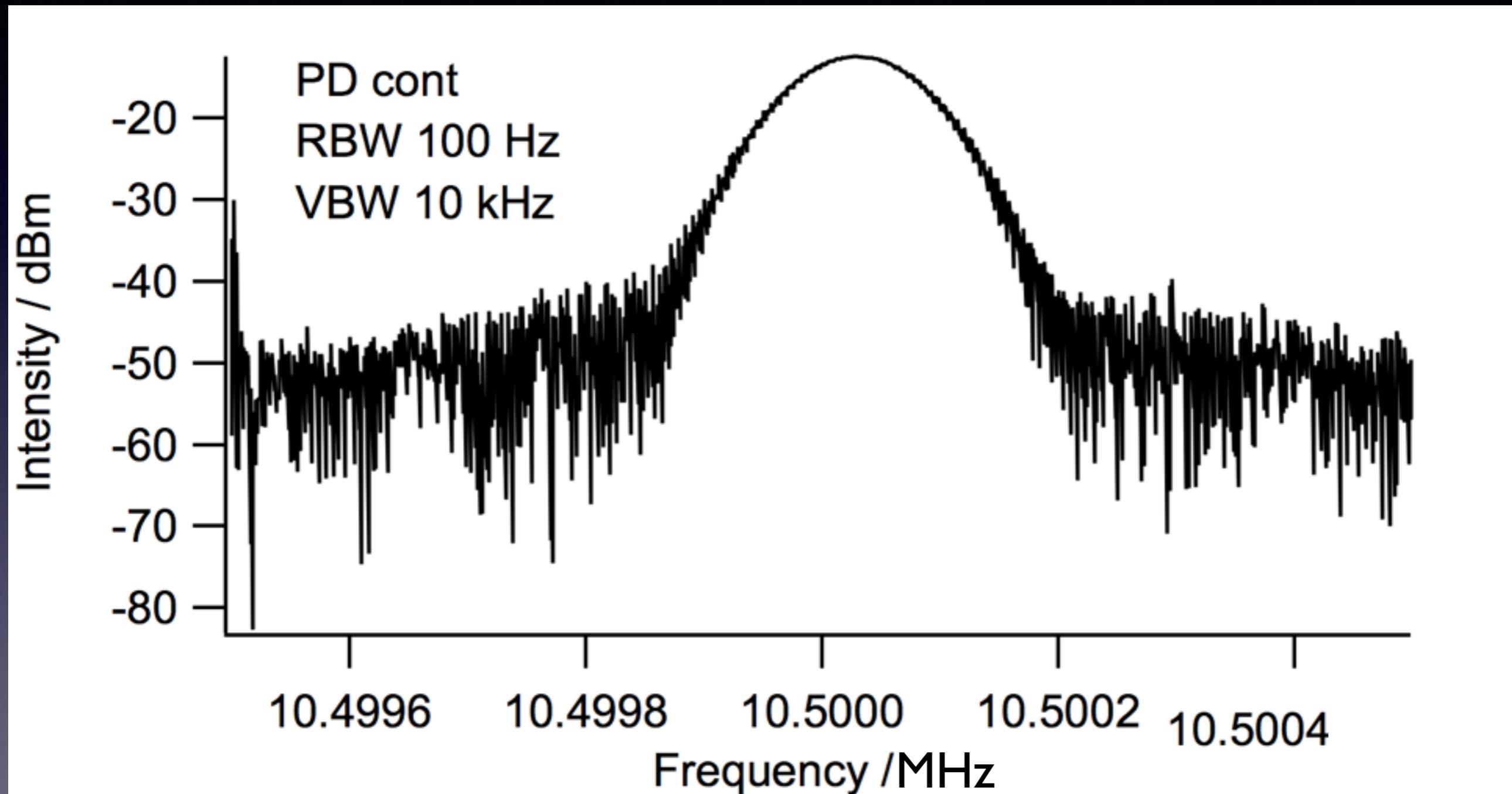
60 kHz/DIV

Span: 600 kHz

TIME

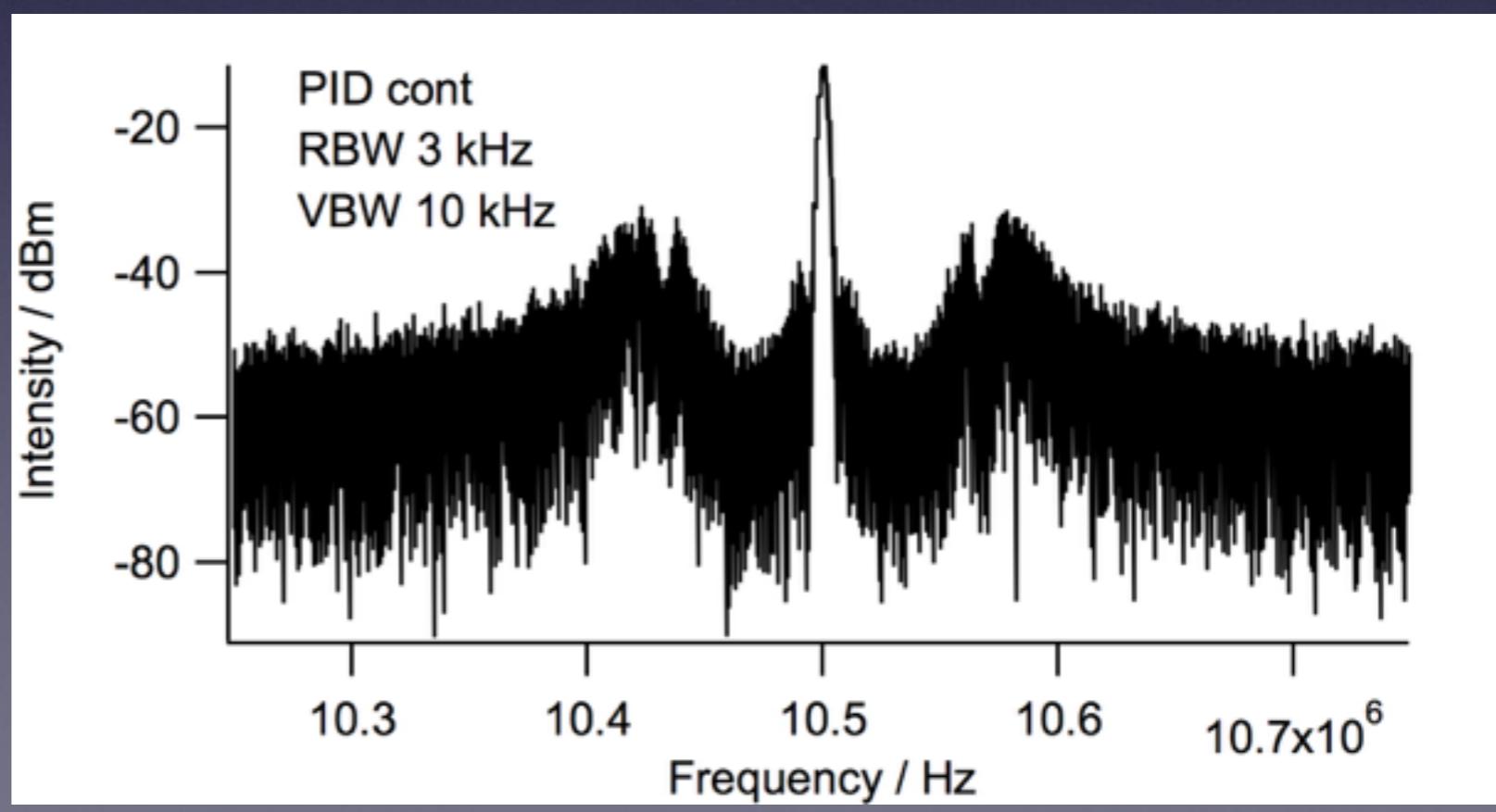
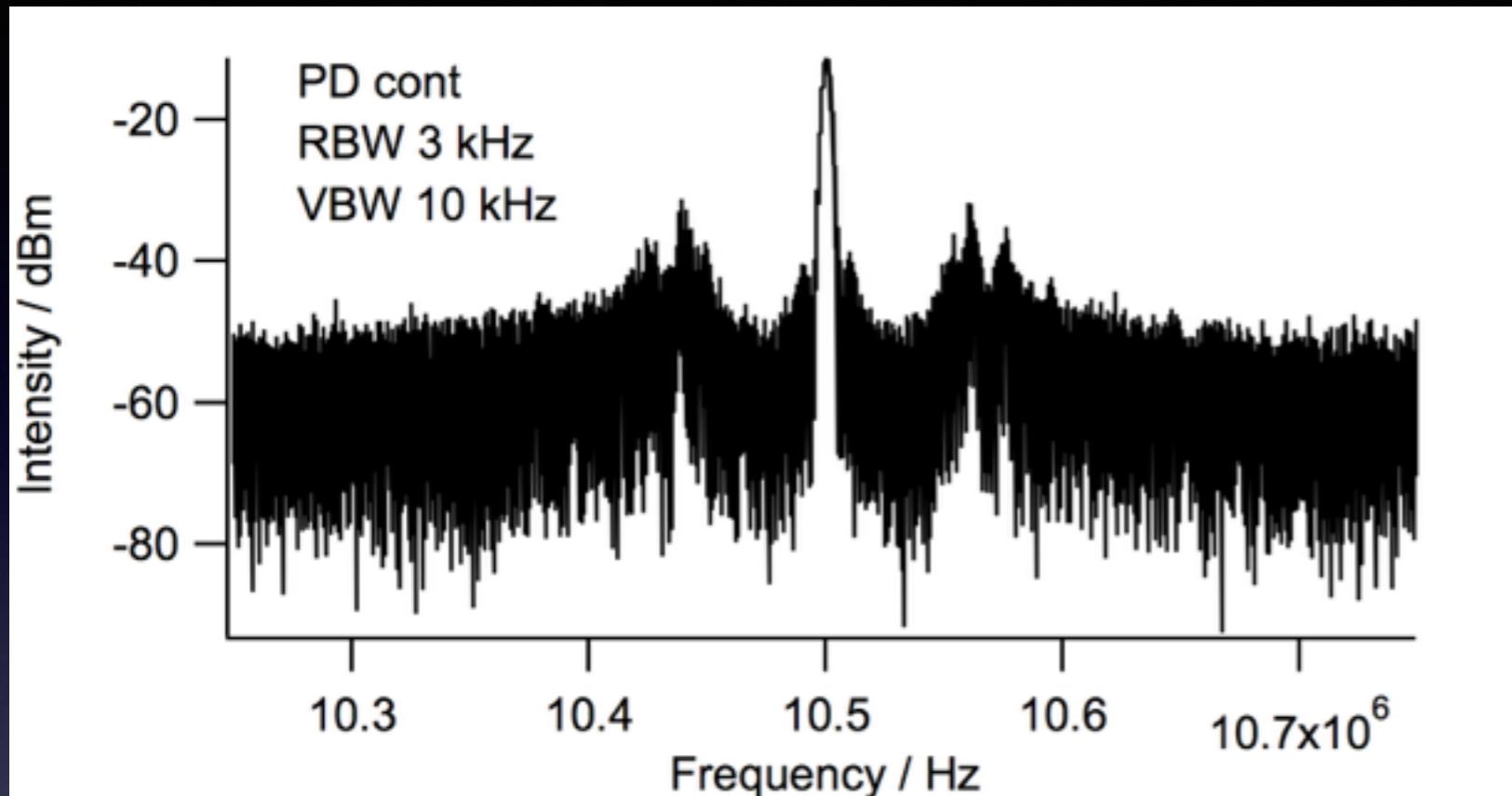
OFF

f_{CEO} stabilization

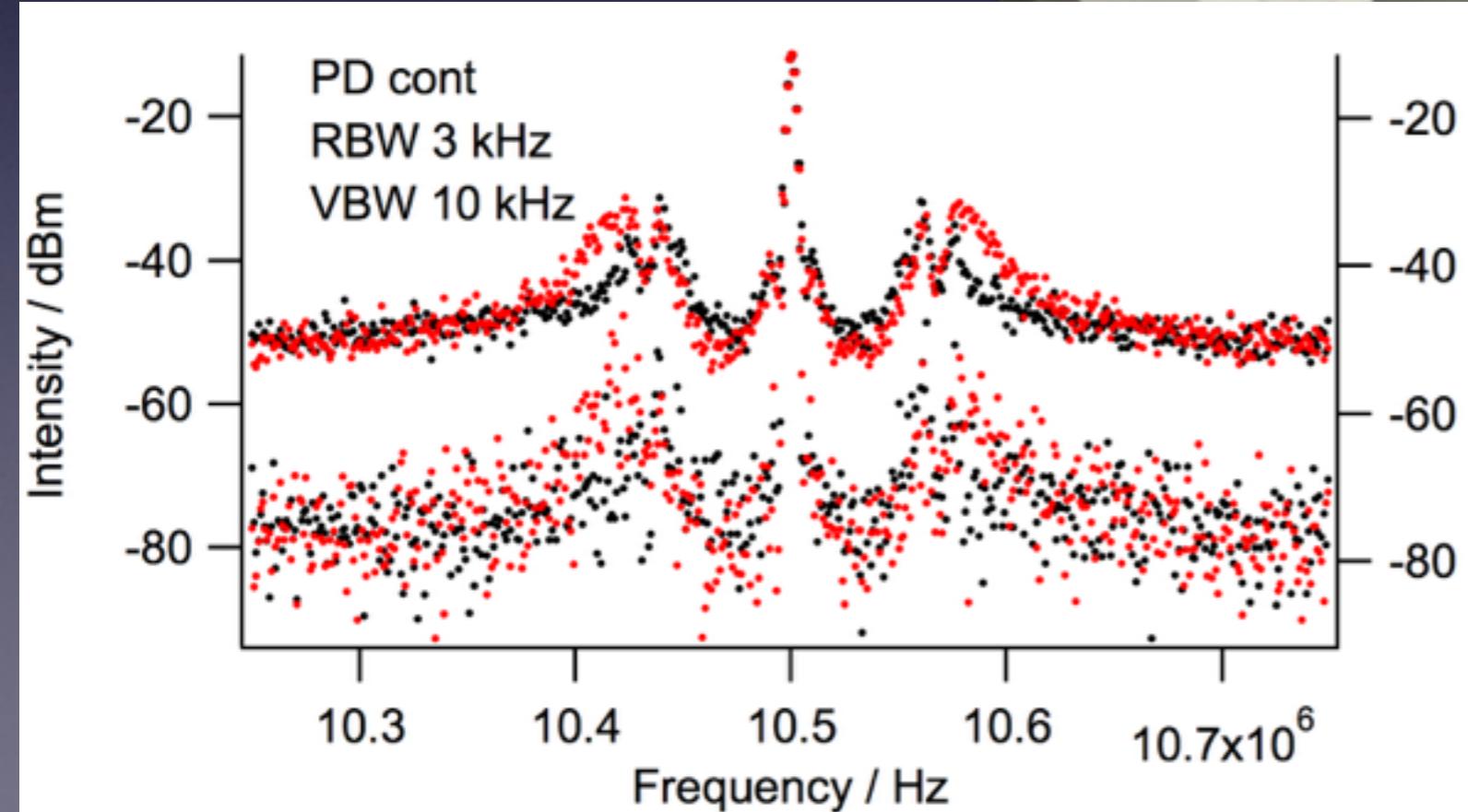
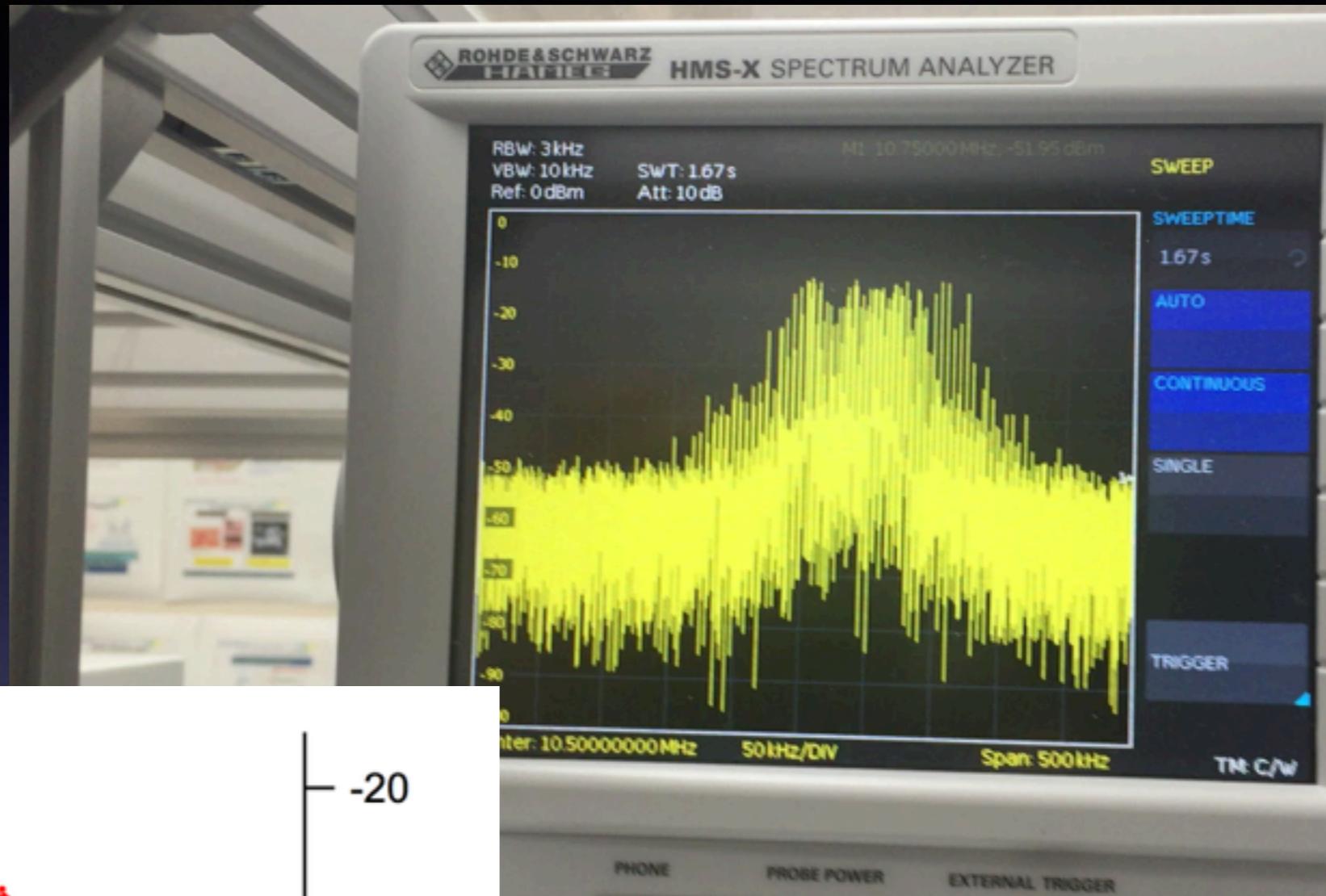


FWHM was less than 100 Hz

f_{CEO} stabilization



f_{CEO} stabilization

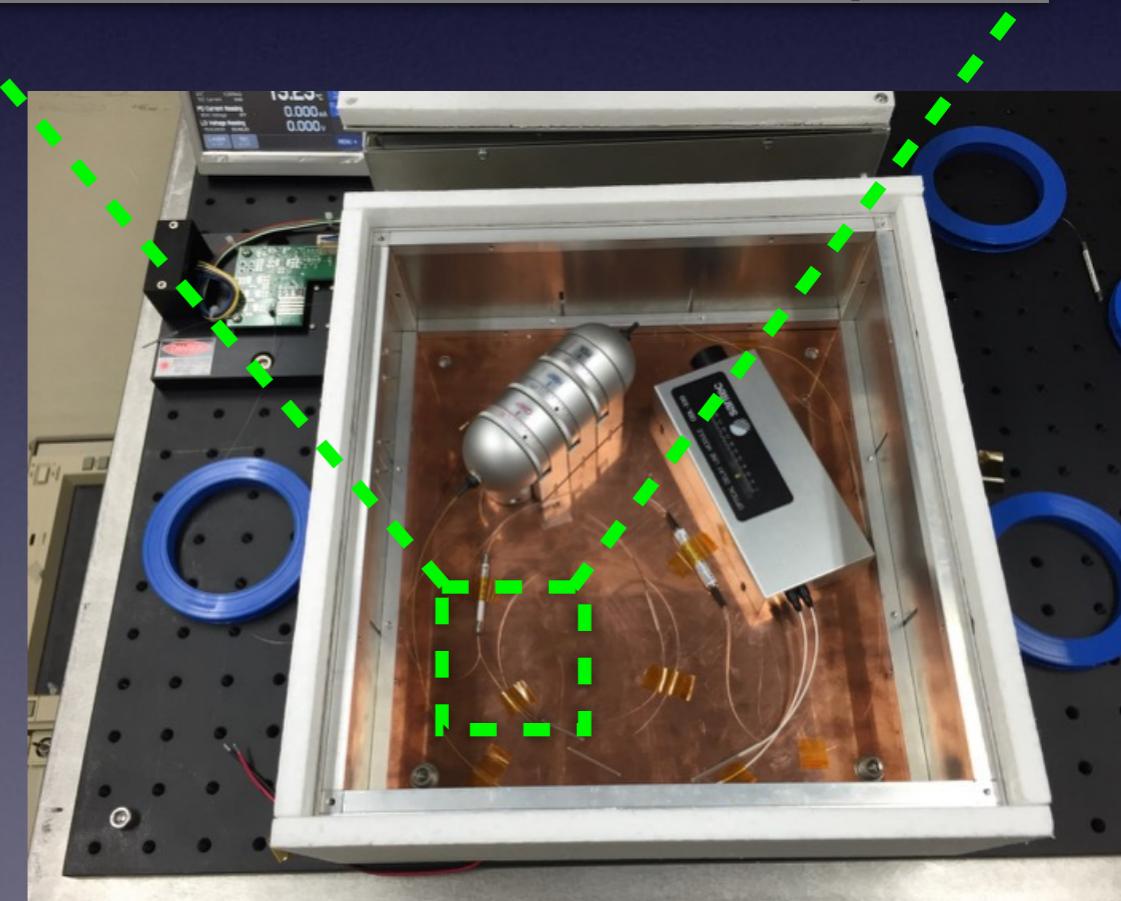
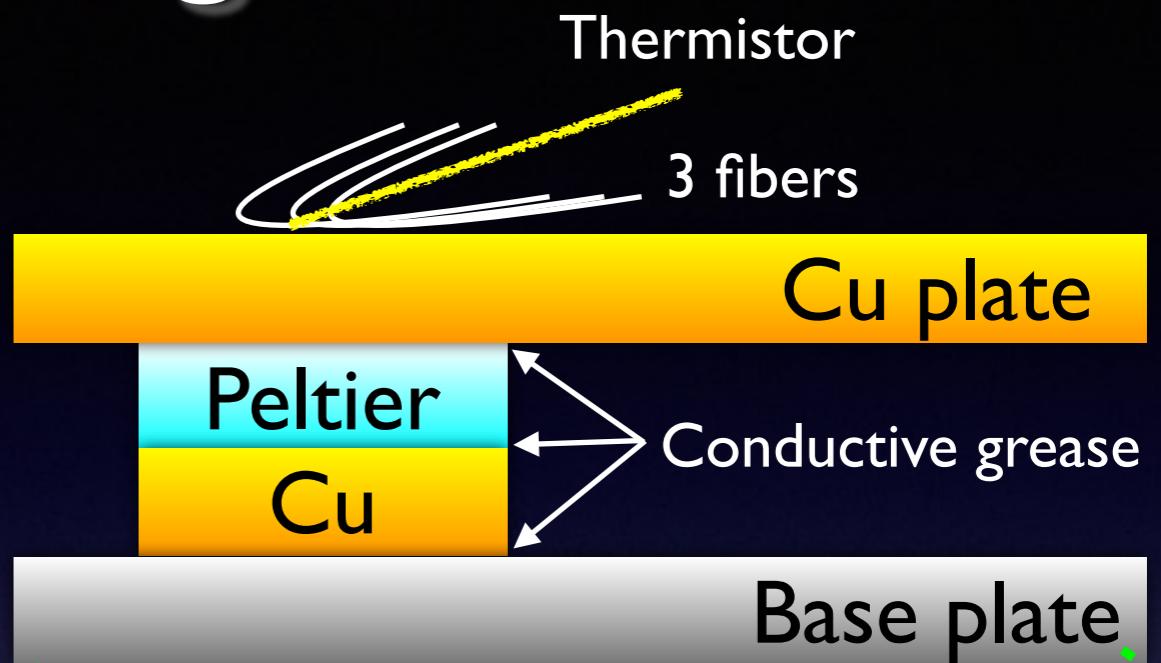
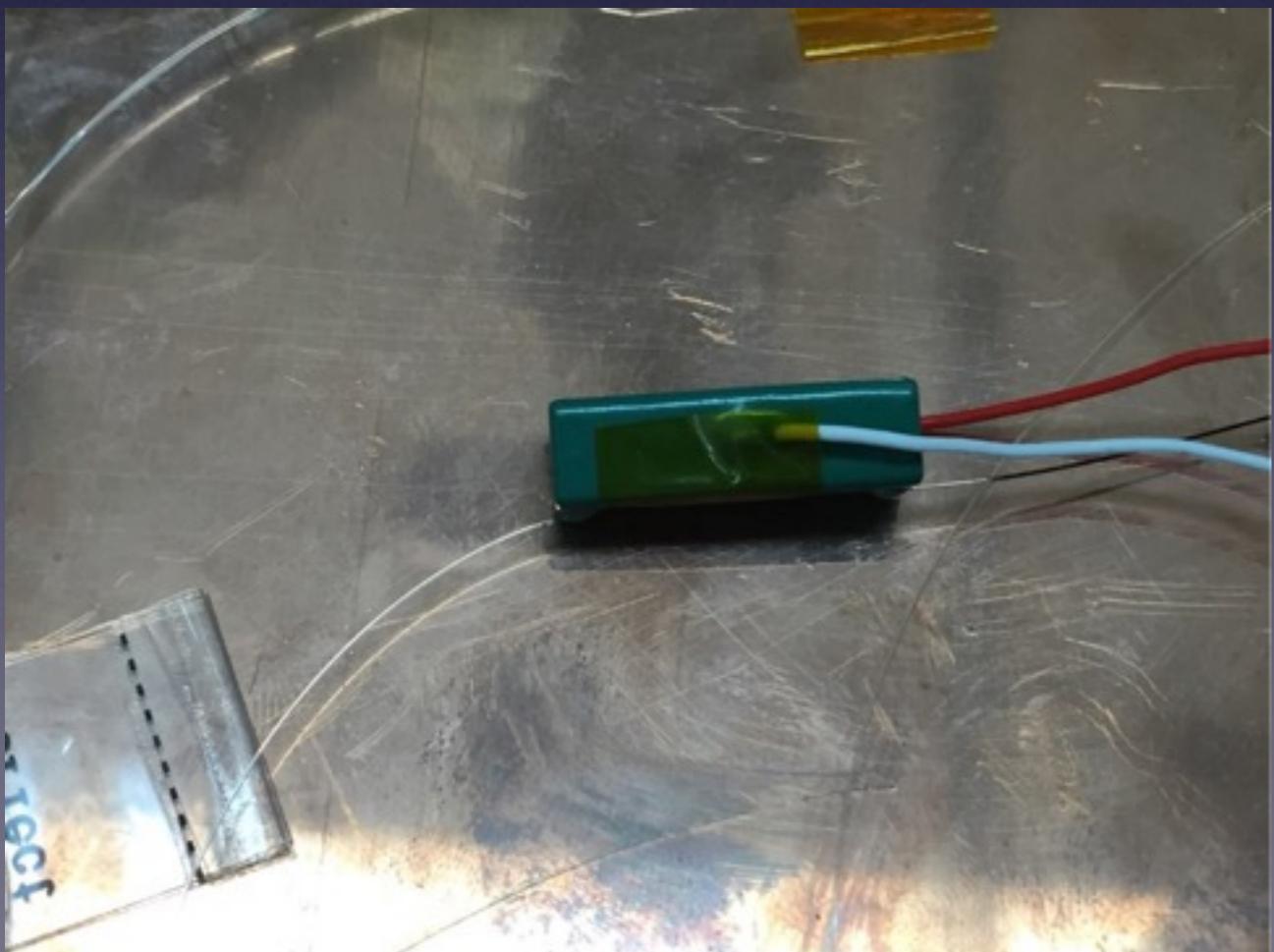


w/o cont
↓
PD cont
↓
PID cont

f_{rep} stabilization

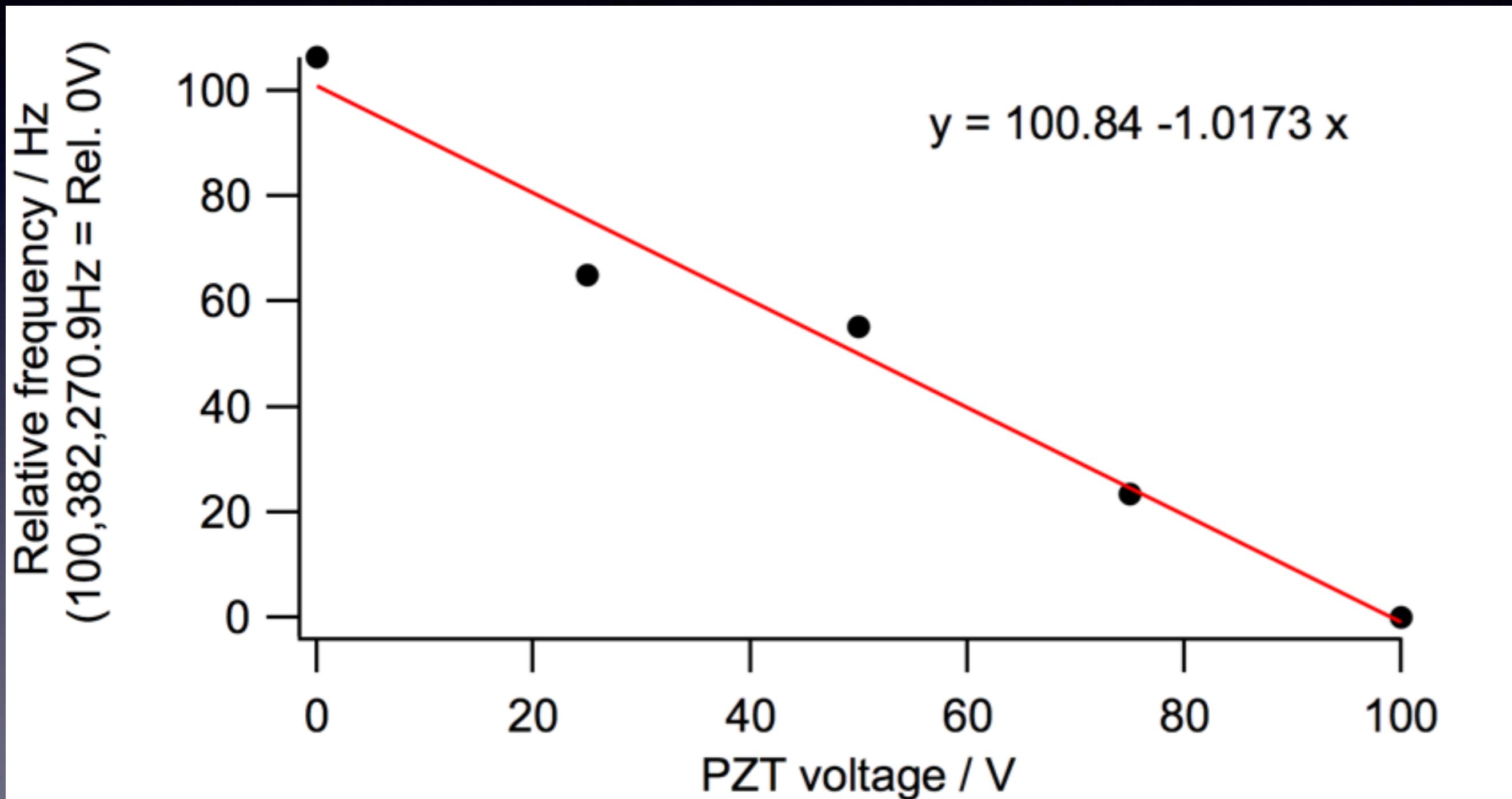
f_{rep} tuning

PZT



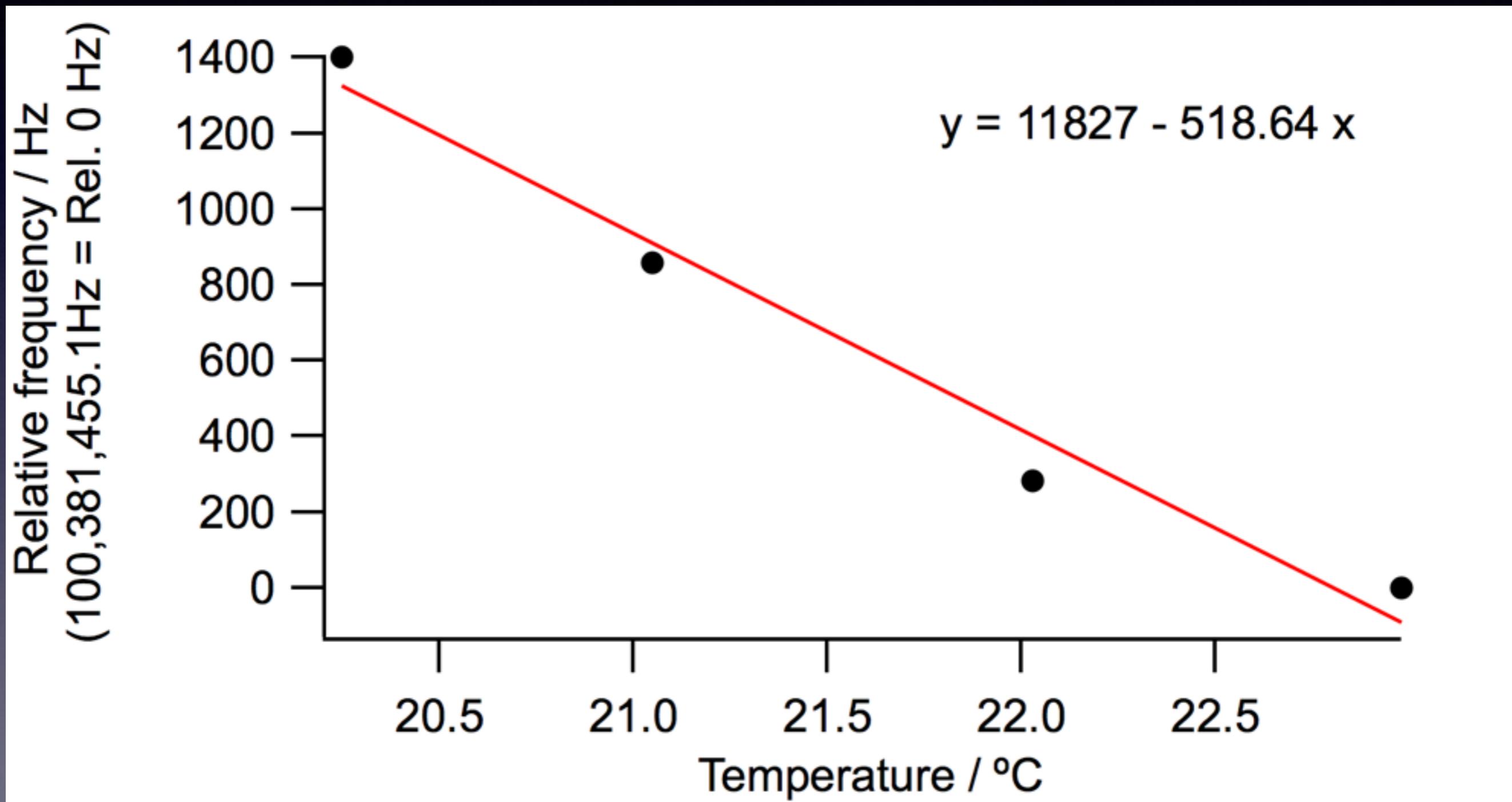
Peltier

f_{rep} tuning - PZT -

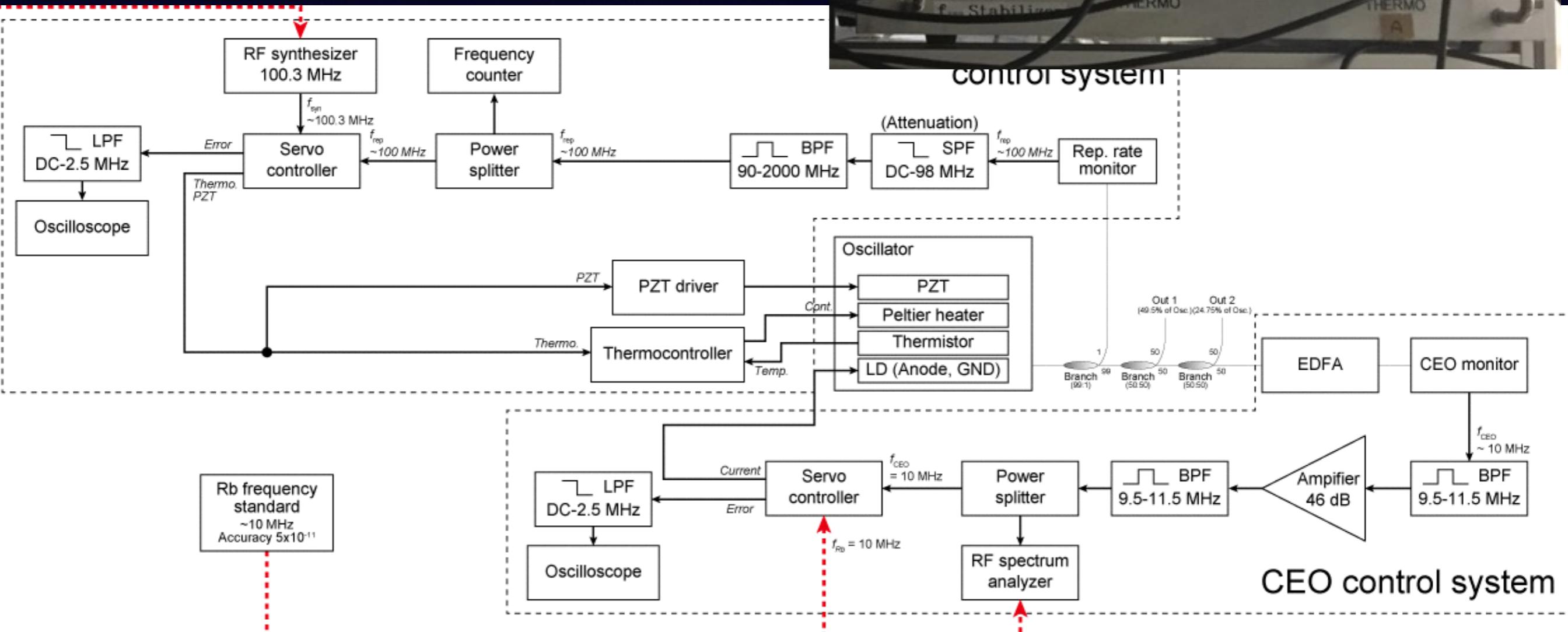


$$\Delta f = 100 \text{ Hz} \rightarrow \Delta L = 2.98 \mu\text{m} \text{ (Spec. } 11.6 \mu\text{m}@100\text{V})$$

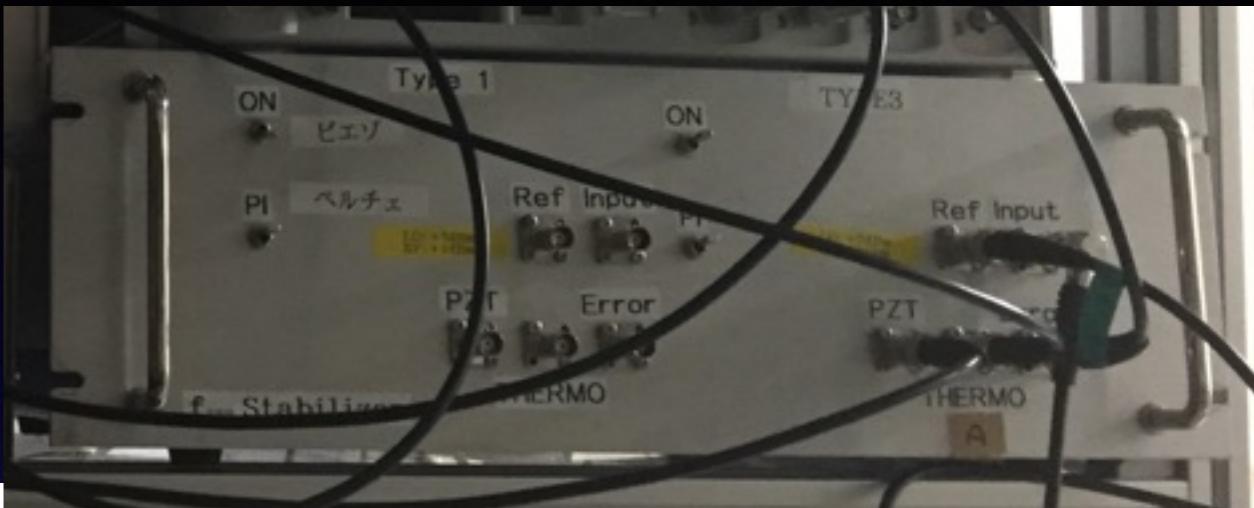
f_{rep} tuning - Peltier -



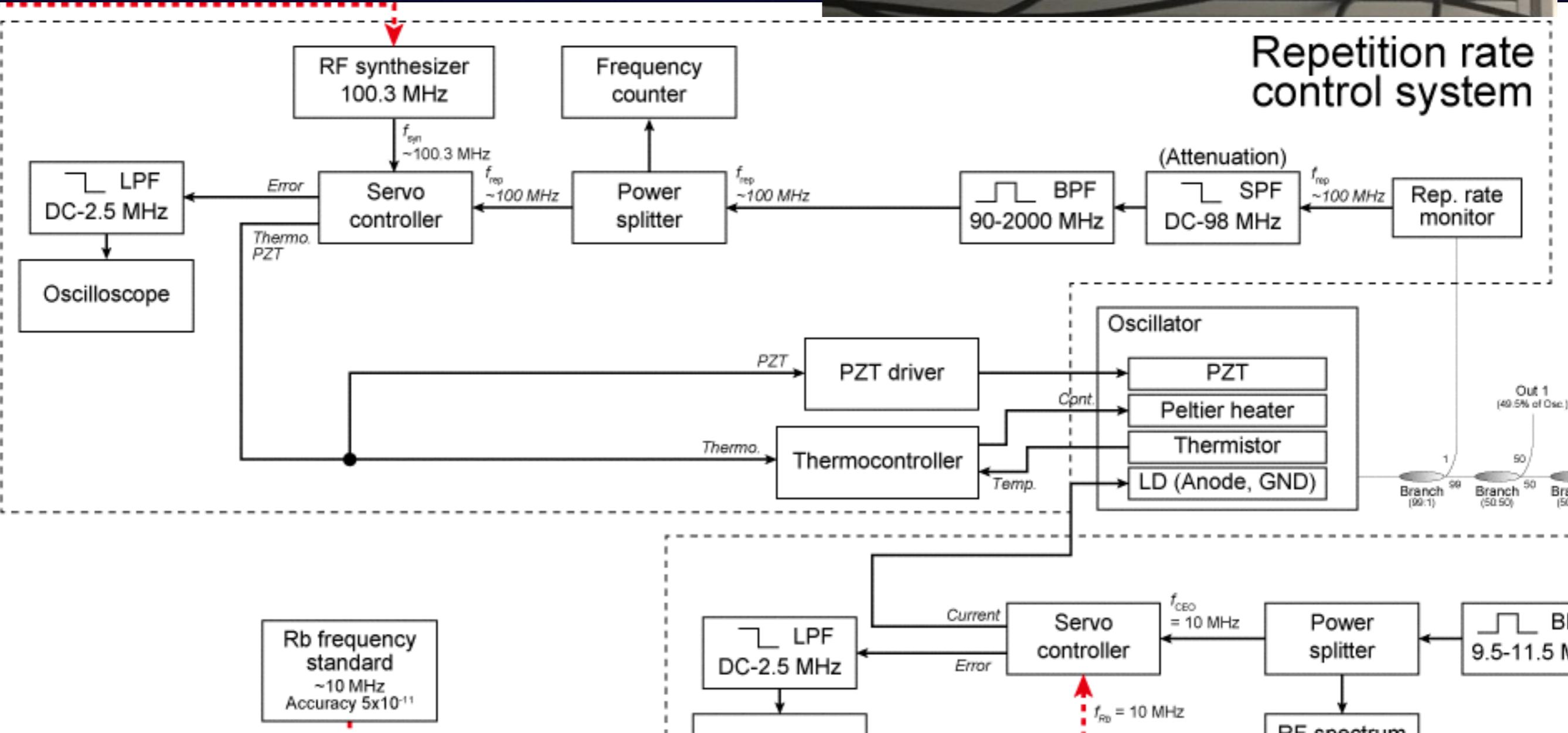
f_{rep} stabilization



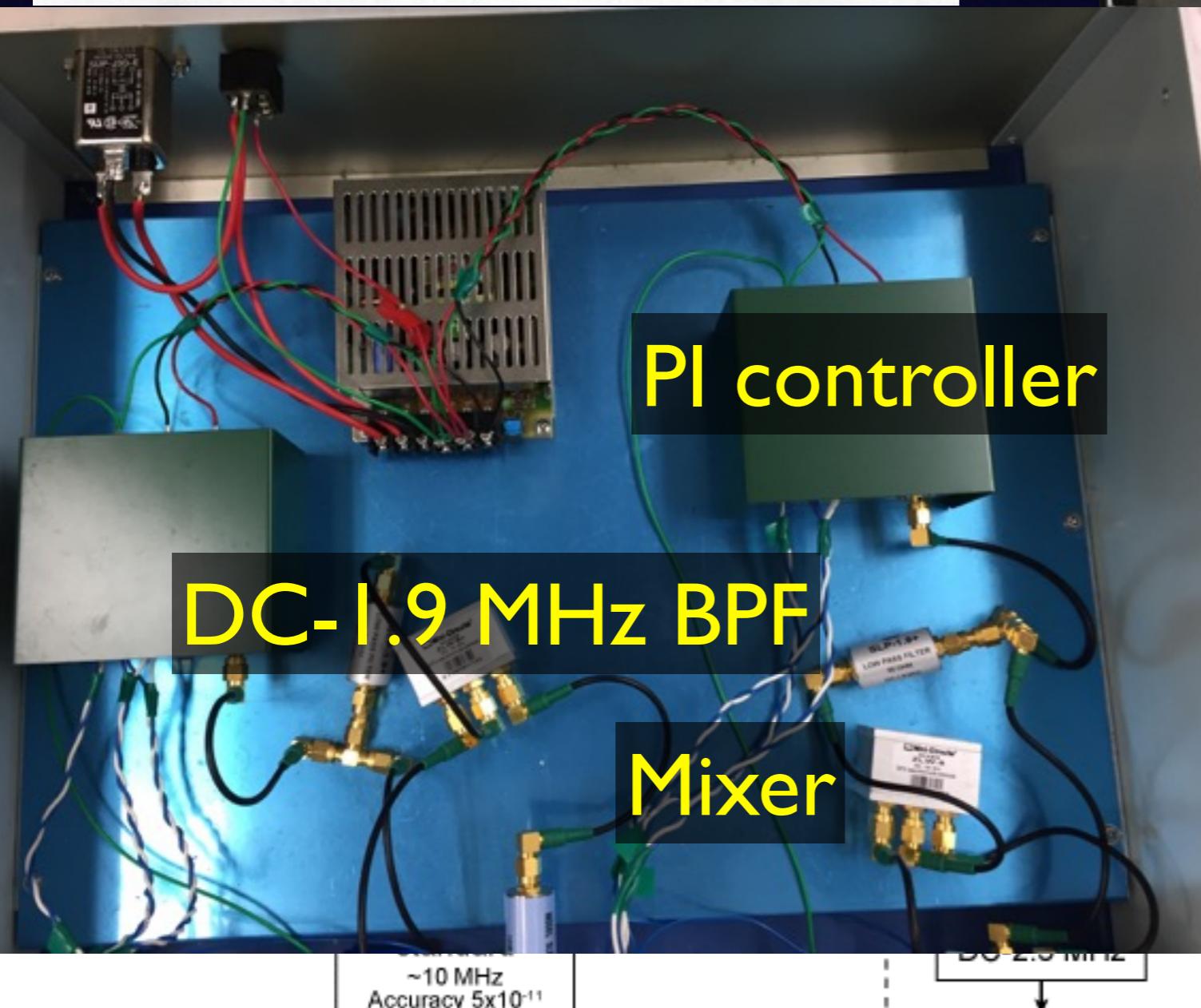
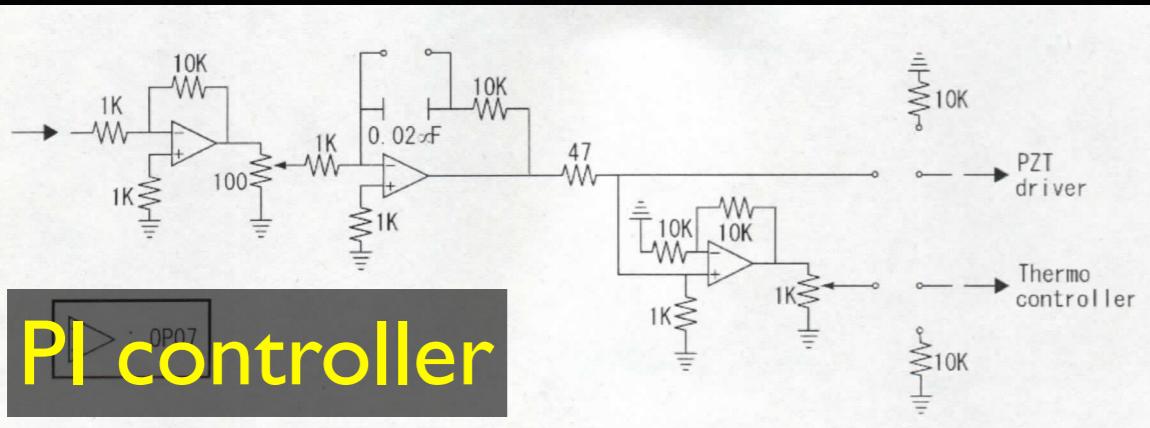
f_{rep} stabilization



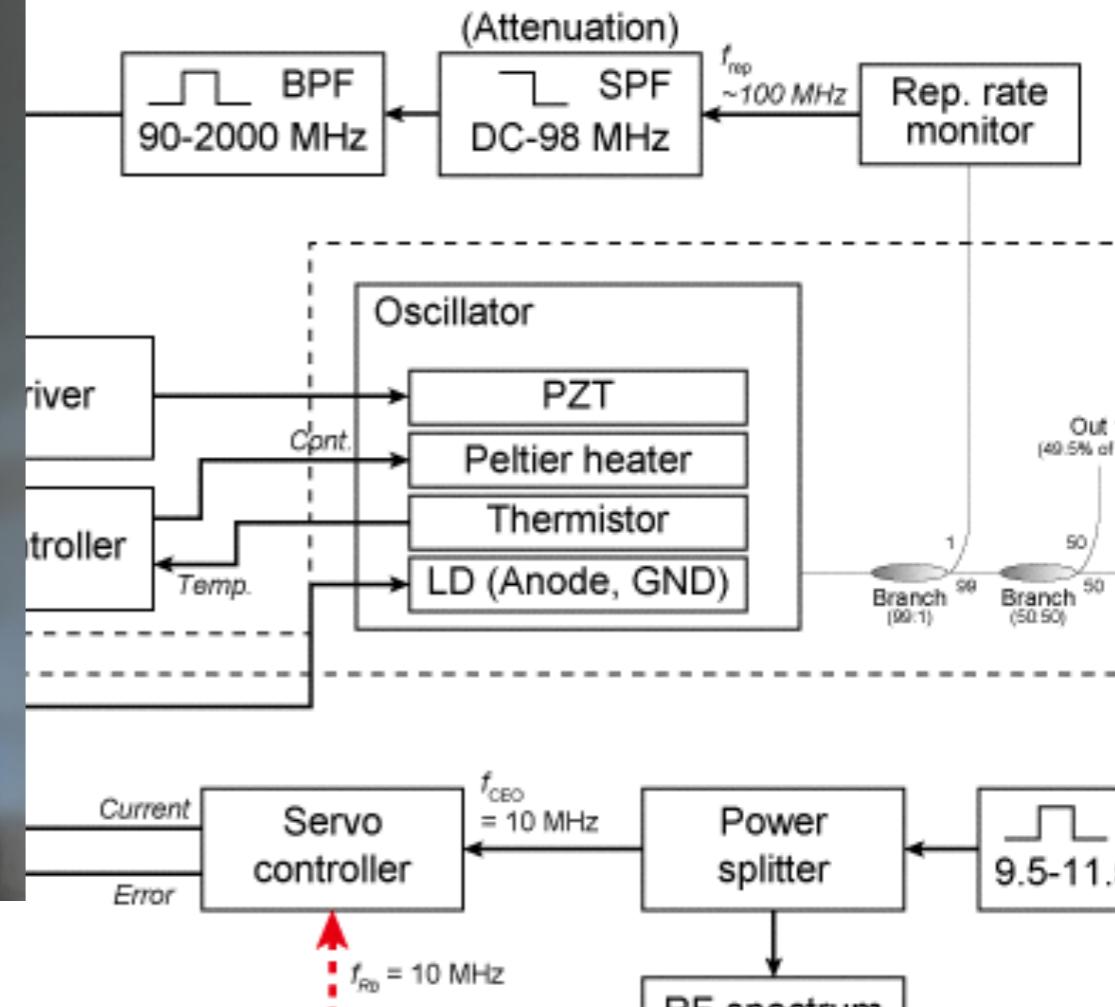
Repetition rate control system



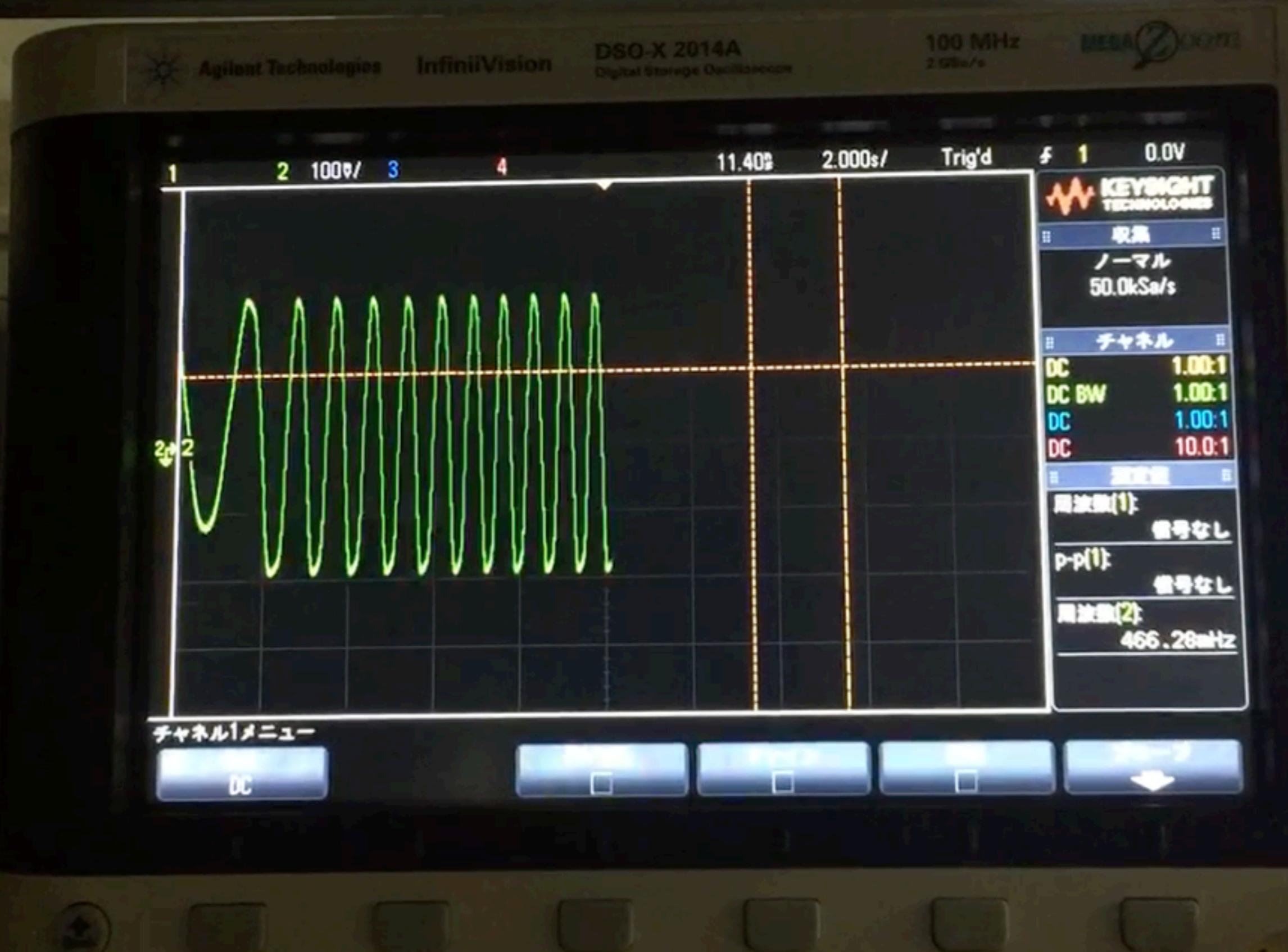
f_{rep} stabilization



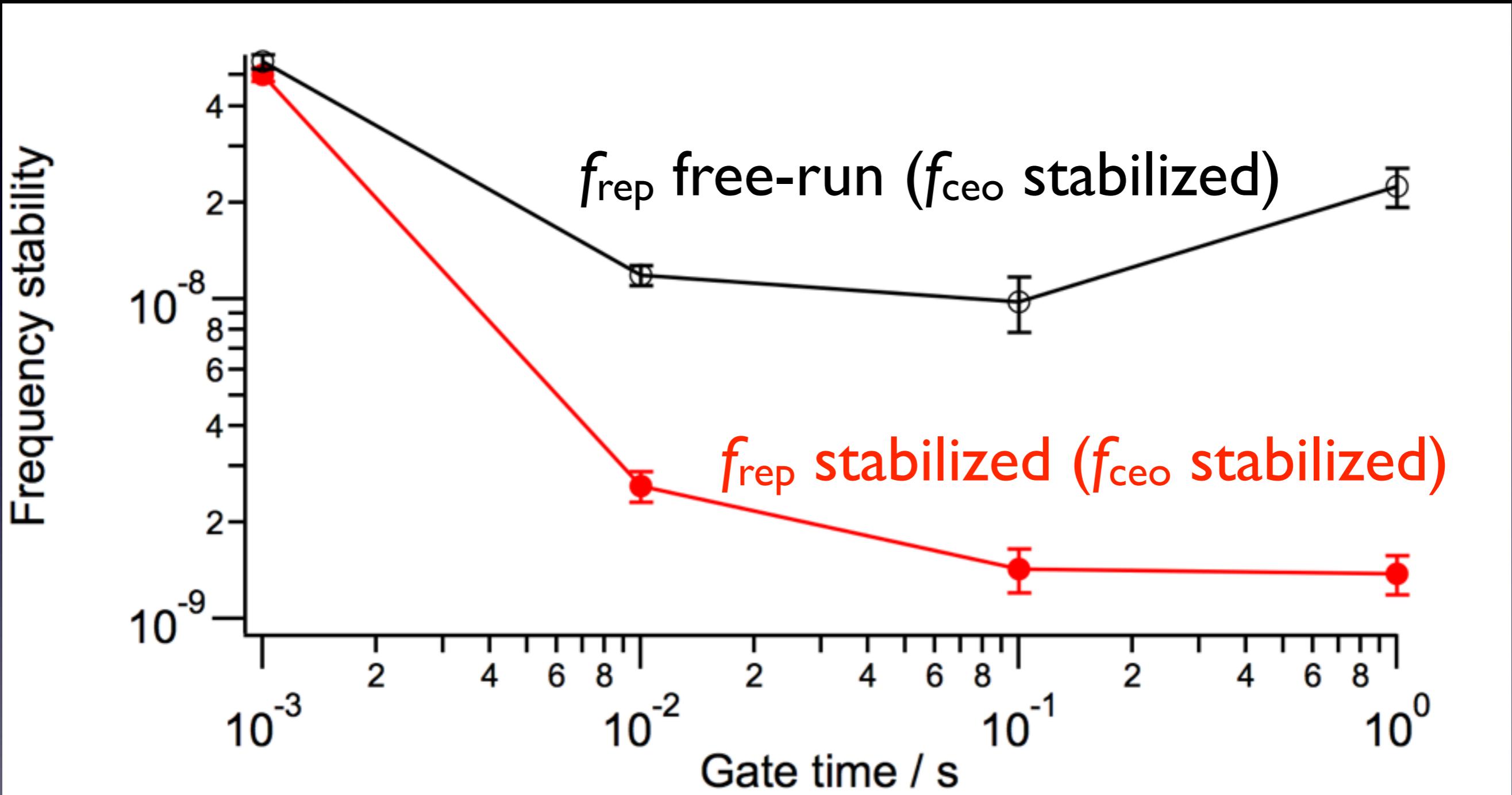
Repetition rate control system



f_{rep} stabilization



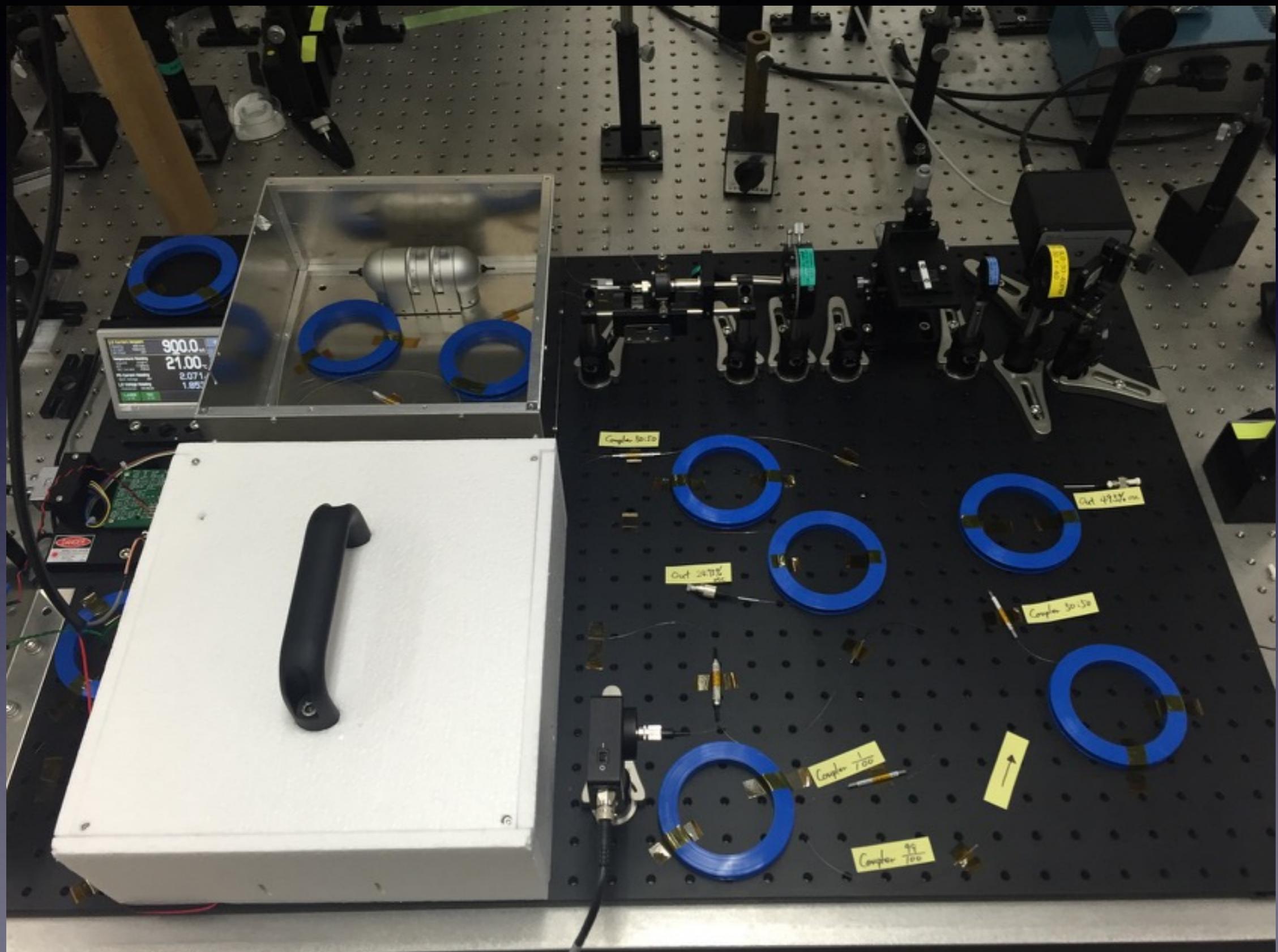
f_{rep} stabilization



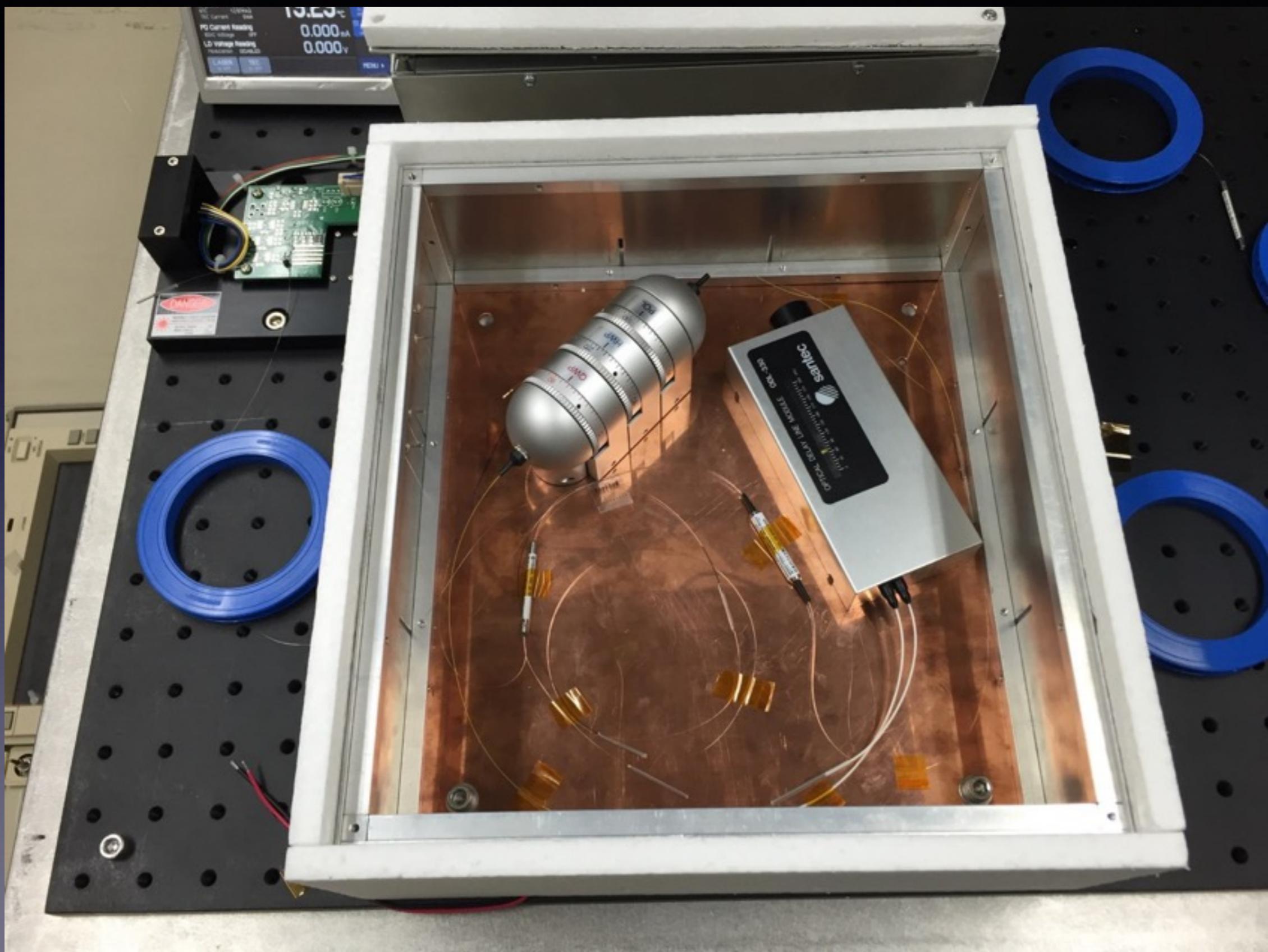
of counts for calculate S.D.: 100
w/o Rb standard for all equipments

Optical setup

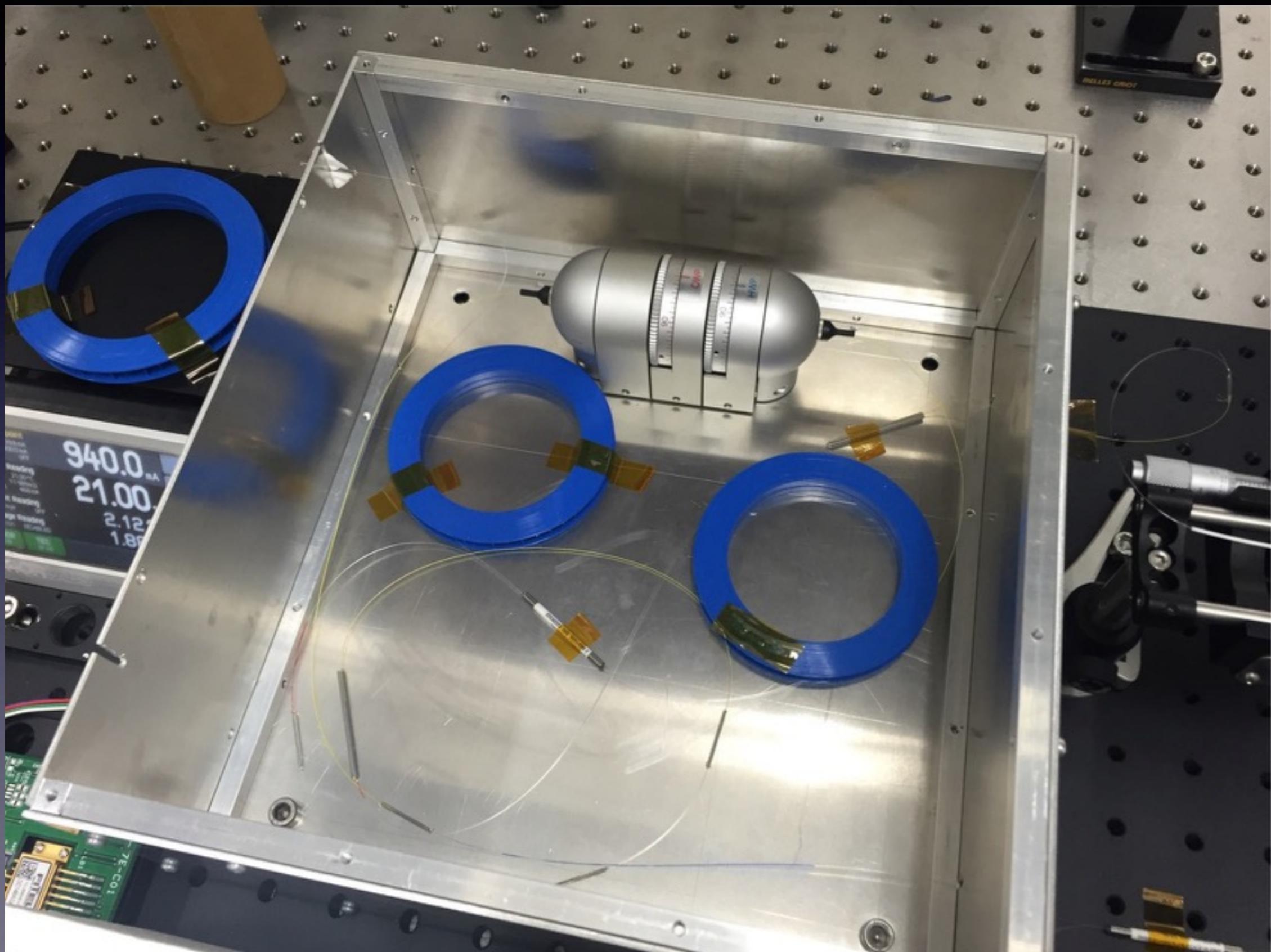
Optical setup



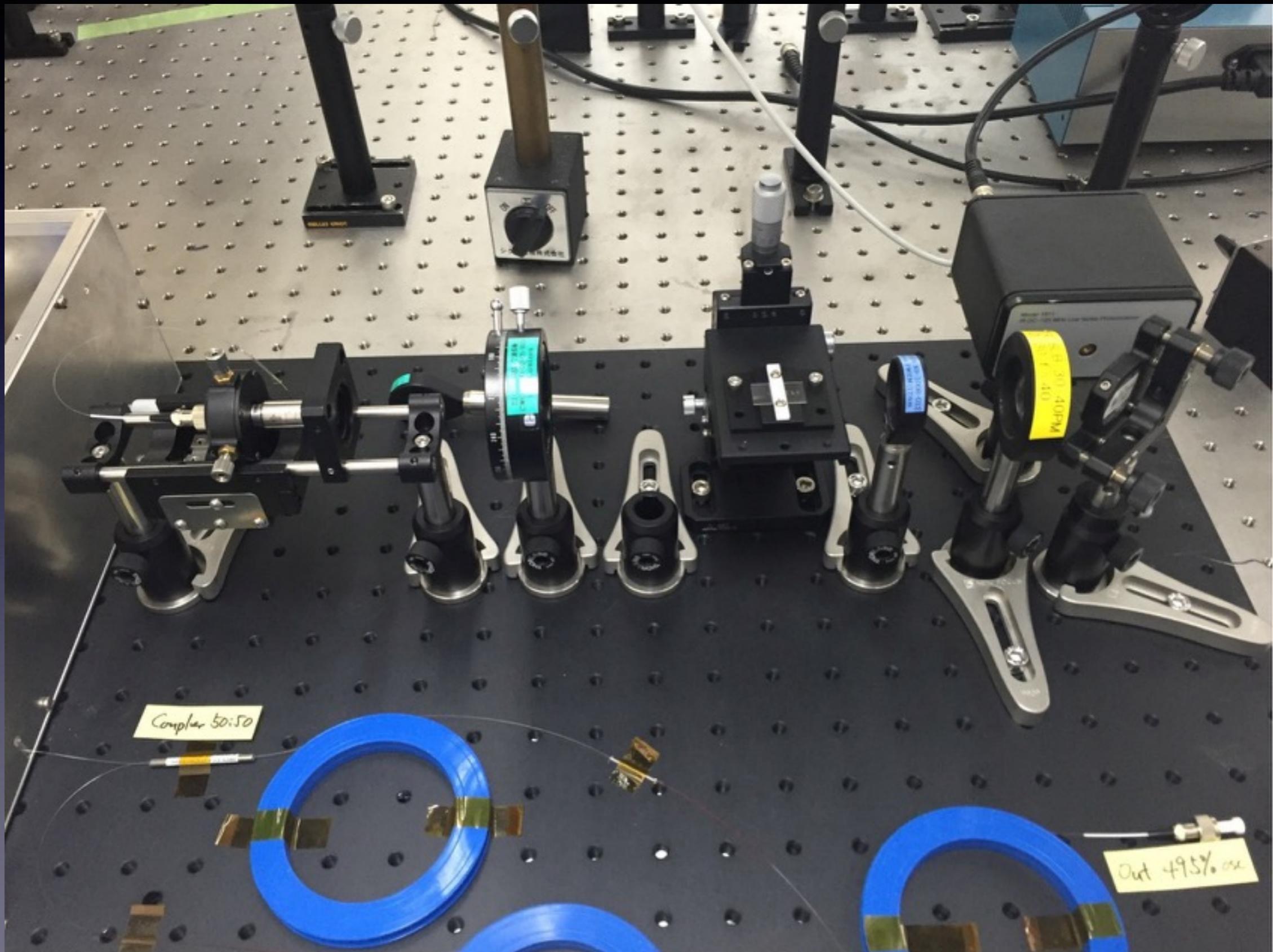
Oscillator



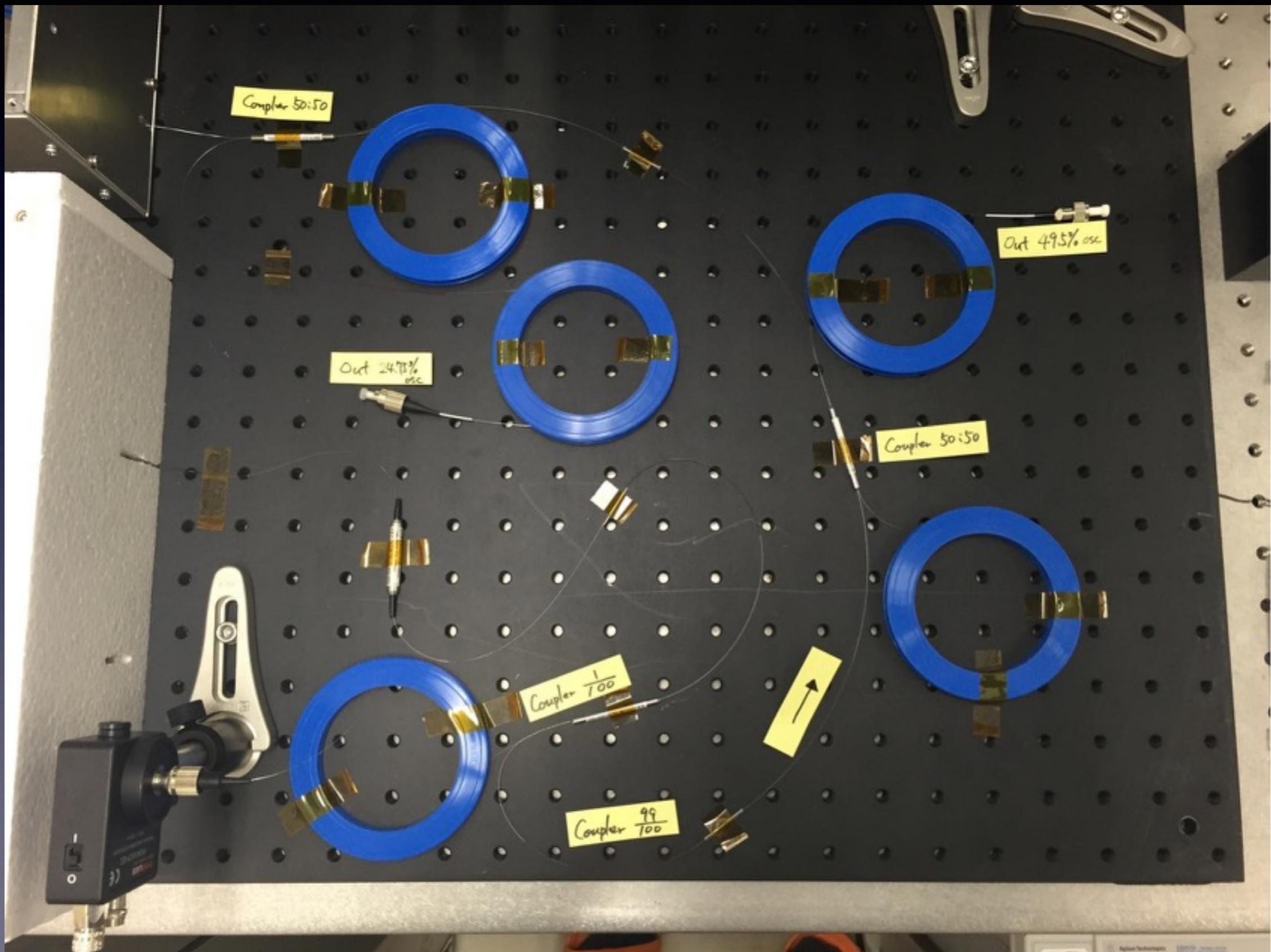
EDFA + HNLF



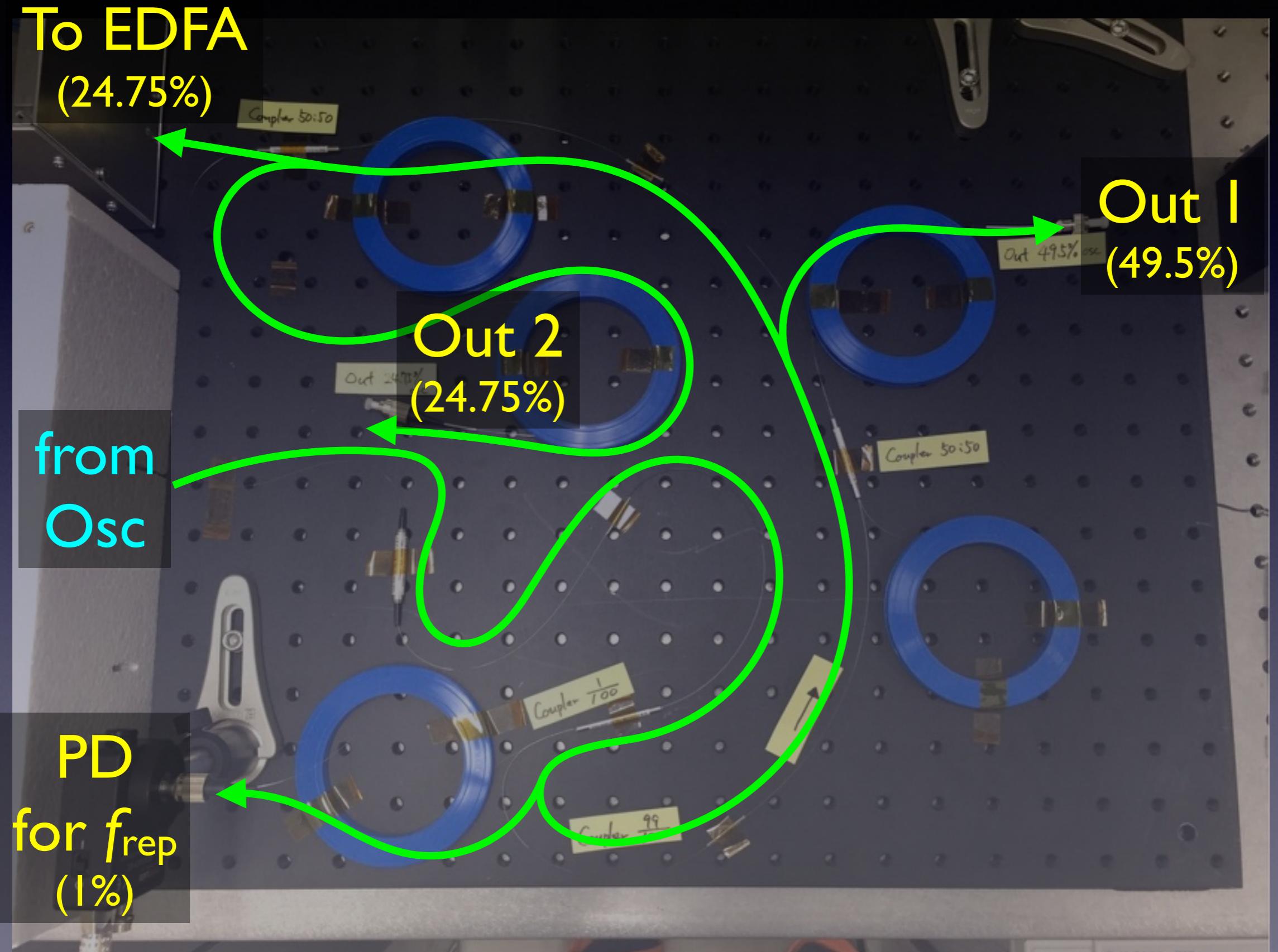
f - $2f$ interferometer



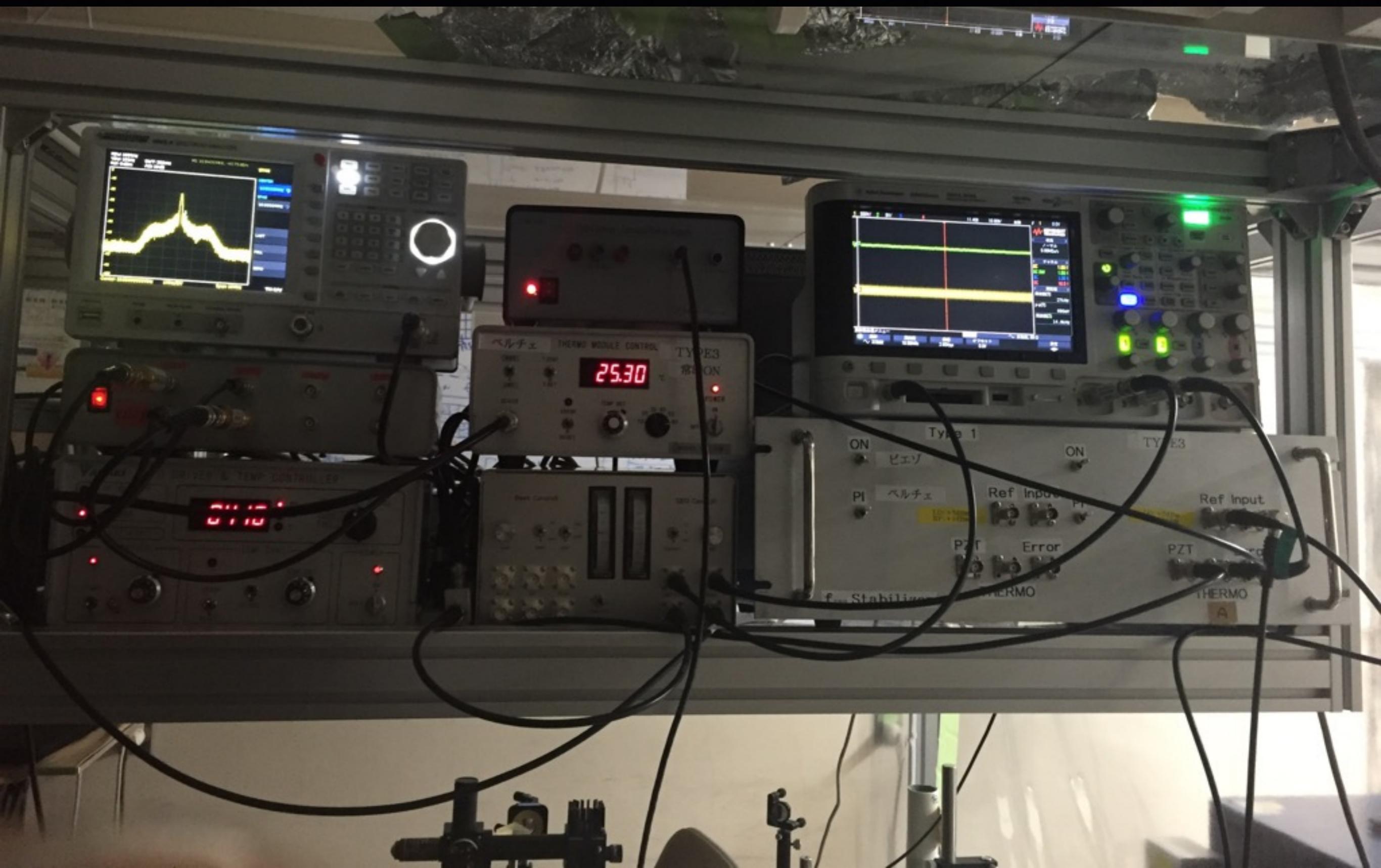
Branches



Branches



Controllers



Controllers

PZT controller

RF spectrum
analyzer

RF amplifier

LD controller

Power supply
for f_{CEO} PD

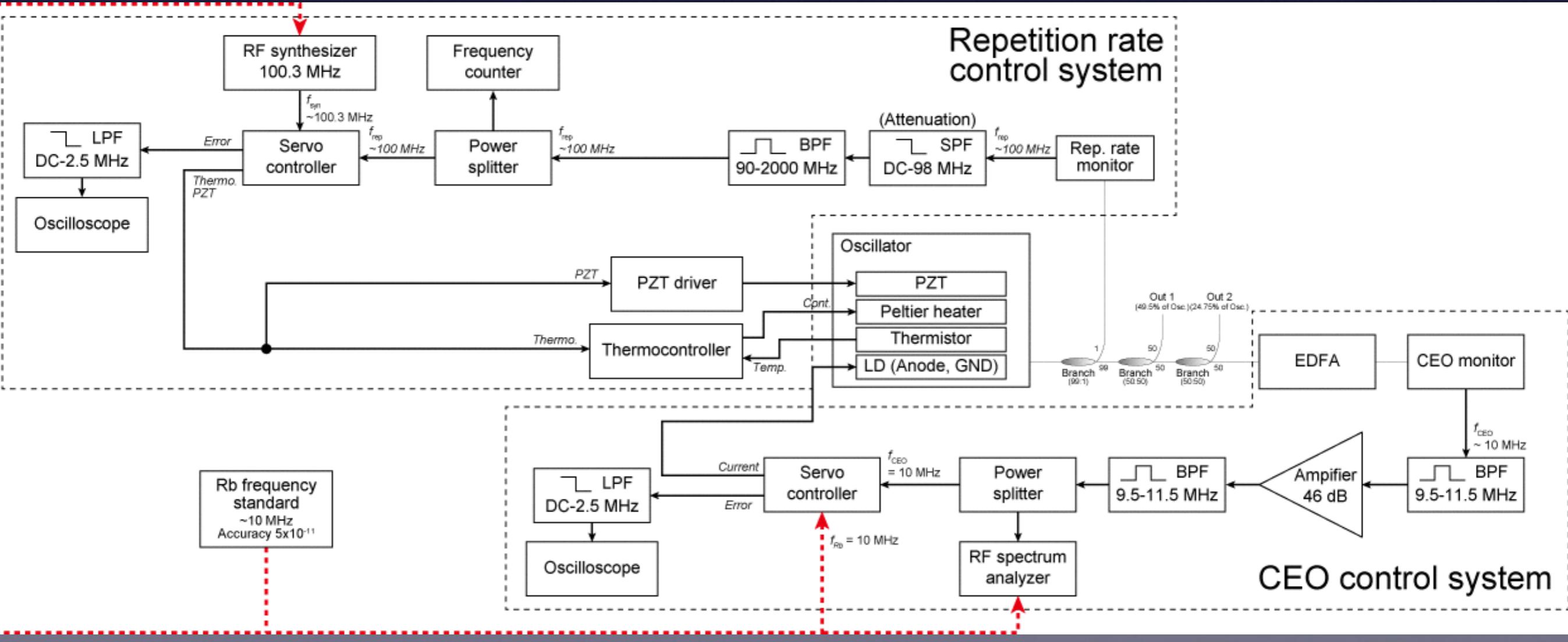
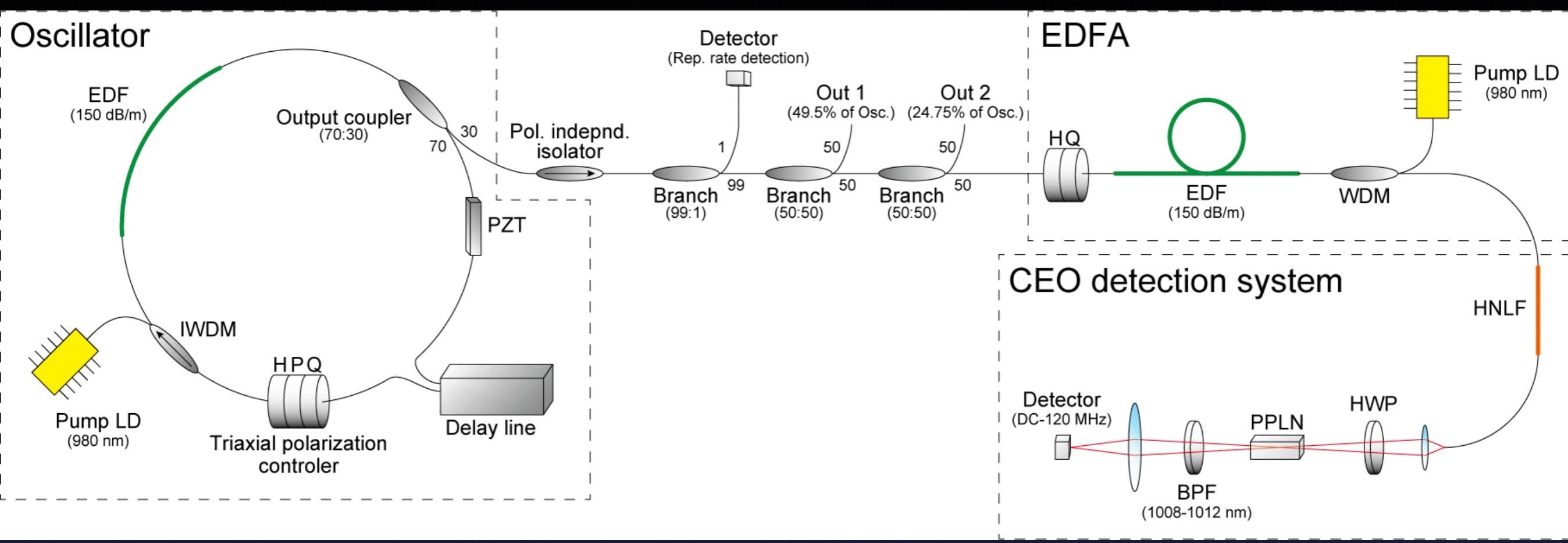
Peltier
controller

f_{CEO} servo
controller

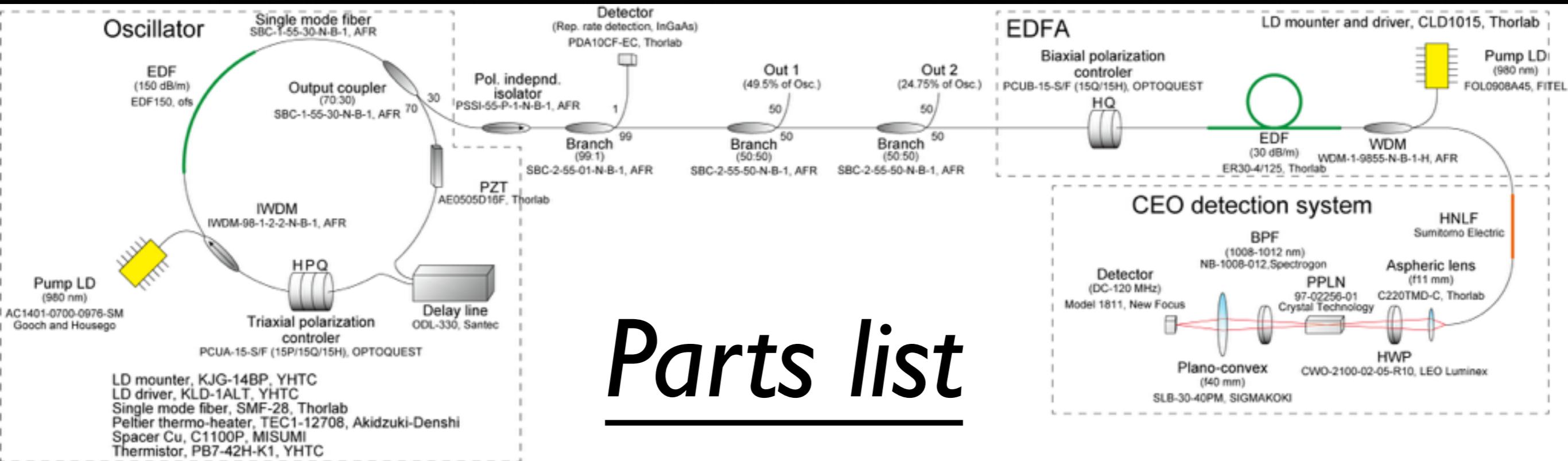
Oscilloscope
(w/ wave generator for f_{CEO})

f_{rep} servo
controller

Rf synthesizer for f_{rep}



Parts list

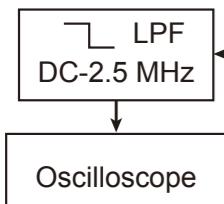


E8257D
Agilent
(250 kHz-20 GHz)

RF synthesizer
100.3 MHz

Frequency counter

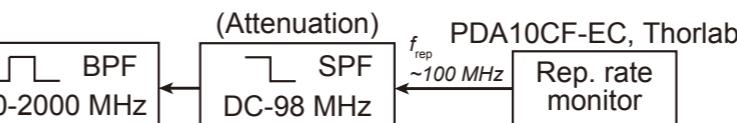
53132A
Agilent
(225 MHz)



Error
Servo controller

f_{rep}
~100 MHz

f_{rep}
~100 MHz



Repetition rate control system

f_{rep}
~100 MHz

PDA10CF-EC, Thorlab

MDT694A, Thorlab

PZT driver

Thermo.
PZT

Thermocontroller
KLT-2改, YHTC

LD driver
KLD-1ALT, YHTC

Oscillator
PZT
Peltier heater
Thermistor
Laser diode
Anode, GND

Out 1 (49.5% of Osc.)
Out 2 (24.75% of Osc.)

Branch (99:1)
Branch (50:50)
Branch (50:50)

Power supply, Model 0901, New Focus
Model1811, New Focus

EDFA

CEO monitor

Rb frequency standard
~10 MHz
Accuracy 5x10⁻¹¹

LPF DC-2.5 MHz

DSO-X 2014A
Agilent

CS-01, AIST
Servo controller

Current
f_{CEO} = 10 MHz

ZFSC-2-6+, Mini-Circuits
Power splitter

SBP-10.7+, Mini-Circuits

RF spectrum analyzer

HMS-X
ROHDE&SCHWARZ

LNA-545
RF BAY
Amplifier 46 dB
BPF 9.5-11.5 MHz

SBP-10.7+, Mini-Circuits

BPF 9.5-11.5 MHz

CEO control system

Oscillator

Specification

LD power	>360 mA @ 21.0 °C
Wavelength	1572 nm (peak), FWHM 37.1 nm
Pulse width	70.0 fs (not optimized)
f_{rep}	100,382,270.9 Hz ± 0.15 Hz @ stabilized (w/o Rb)
f_{ceo}	BW < 100 Hz @ stabilized (~100 kHz @ free run)
Power	9.49 mW (Out1, 4.7 mW; Out2=2.4 mW)
Notes	Delay line ($\Delta f_{\text{rep}} \sim 3.3 \text{ MHz} @ \Delta 330 \text{ ps}$) PZT ($\Delta f_{\text{rep}} \sim 100 \text{ Hz} @ \Delta 100 \text{ V}$) Peltier ($\Delta f_{\text{rep}} \sim 1 \text{ kHz} @ \Delta 2^\circ \text{C}$)

EDFA for f_{ceo} detection

LD power	800 mA @ 21.0 °C
EDFA length	4 m
Output	55.0 mW @ 2.4 mW input

Future work

Move to M306 room

Construction of dual-comb system

- ✓ Confirmation of EOM comb system
- ✓ Construction of EDFA system (x2)
- ✓ Synchronization of PZT-comb to RIO
- ✓ Synchronization of RIO to EOM-comb
- ✓ Evaluation of relative-line width between PZT- and EOM-combs
- ✓ Enclosure for EOM comb?