Phase locking of optical frequency comb using laser-diode pumped Kerr-lens mode-locked Yb:KYW laser to RF reference

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Introduction

- **Goal**
  Optical frequency comparison.
  ➔ Long-term continuous operation / Low running cost required.
- **Achievement**
  – Kerr-lens mode-locking of Yb:KYW Laser
  – One-octave spanning by using photonic crystal fiber(PCF).
  – Phase locking of f_{CEO} and f_{rep} to RF reference.

Comparison with other lasers

- **Titanium-doped sapphire(Ti:Sa) Laser**
  Props – Same frequency control method as used in CW laser.
  Cons – High-power pump laser required.
  ➔ Instabilities in long-term operation and high running costs.
- **Fiber laser**[1]
  Props – Turn-key and long-term operation.
  Cons – Special techniques required for frequency control.

Yb:KYW Laser

(Ytterbium-doped potassium-yttrium-tungstate laser)

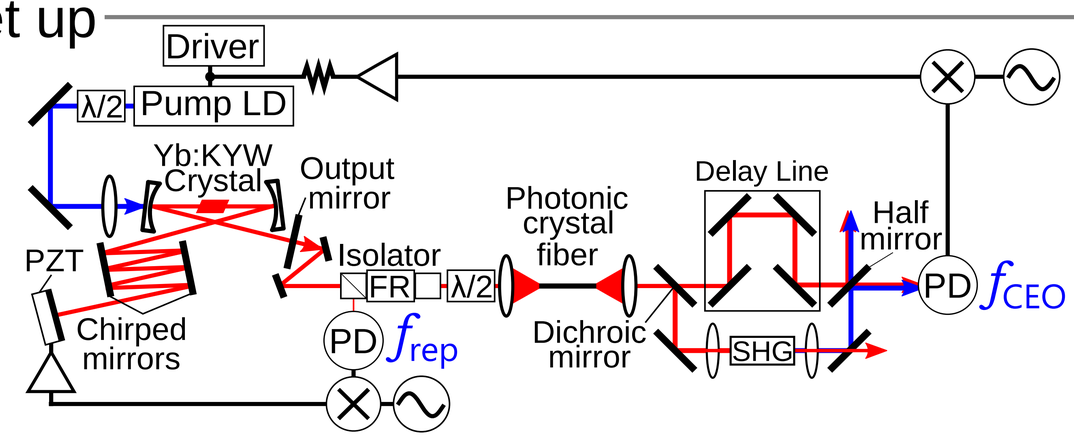
- **Solid-state laser**
  Frequency contorl method used in Ti:Sa may be applicable.
- **Pump wavelength of 981 nm**
  Direct LD pumping is possible.
- **Small quantum defect**
  Operation with passive air-cooling.

Mode-locking has been achieved[2].
High f_{rep} is realized[3].
f_{CEO} and f_{rep} are contolled[4,5].

This work

- High efficient Kerr-lens mode-locked laser.
- Long-term mode-locking > 1month.
- One-octave spanning by using PCF without using amplifier.
- Phase locking f_{rep} and f_{CEO} to RF reference.
- Detection of beat with CW laser and frequency counting.

Set up



Mode-locked laser

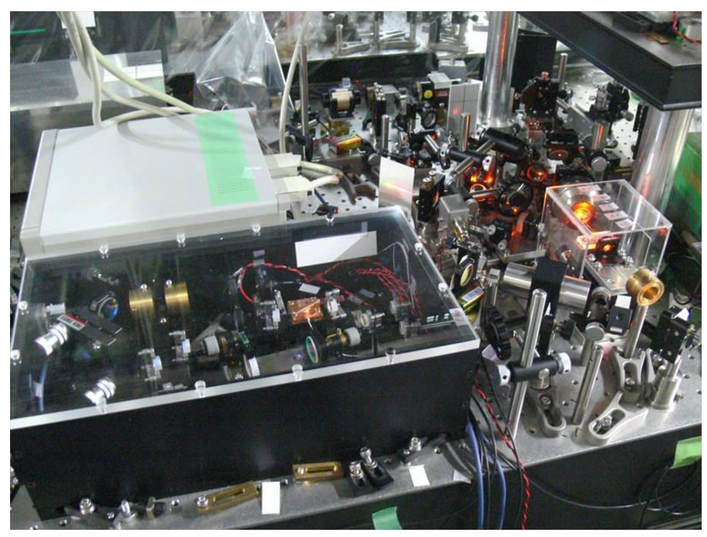
Pump laser : 981 nm 750 mW
Crystal : 5% doped, 1mm
Output mirror : 92.5%
Cavity length : ~1.7 m

Spectral broadning

Fiber length : 5 cm
Core diameter : 3.3 μm
Zero dispersion wavelength : 890 nm

Self-referencing

SHG crystal : 1 mm BBO

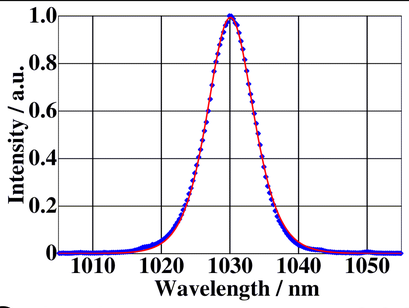


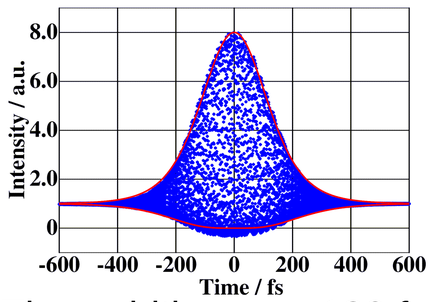
- Laser cavity sealed
- Base-plate temperature controled

➔ Mode-locking maintaines over 1 month.

Experiment

Mode-locked Yb:KYW laser

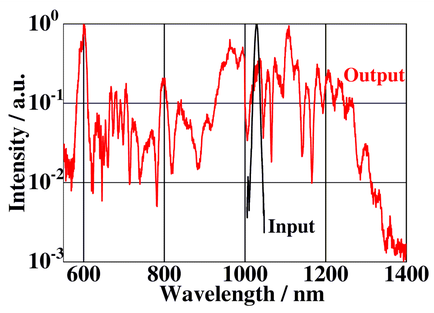




Output power : 360 mW
Center wavelength : 1030 nm
Spectrum width : 8.0 nm
Repetition rate : ~90 MHz

Time width : 180 fs
Time-bandwidth product : 2.5

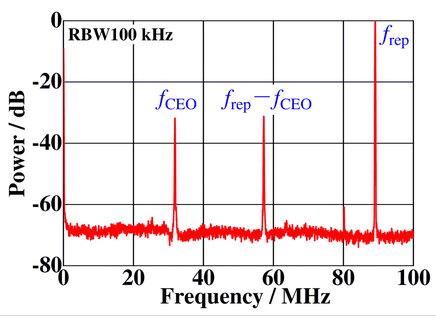
Spectral broadning by photonic crystal fiber



Input power : 360 mW
Output power : 200 mW
Broadend spectrum : 600 ~ 1200 nm

Over one octave

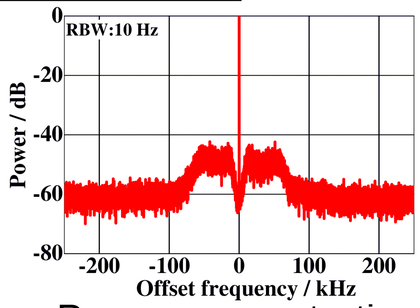
f_{CEO} and f_{rep} detection



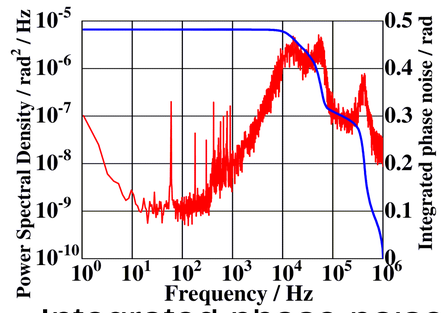
The way of locking

- f_{rep} : Cavity length by PZT
- f_{CEO} : Injection current of pump LD

f_{CEO} locking

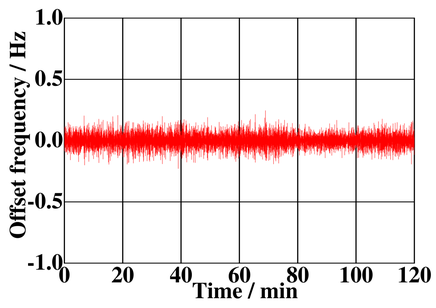


Power concentration
90 % in 25 Hz
(250 kHz span)



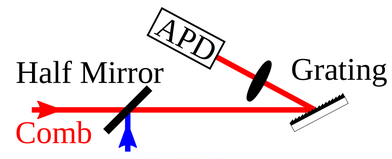
Integrated phase noise
0.48 rad
(1 Hz ~ 1MHz)

Frequency counting of f_{CEO}

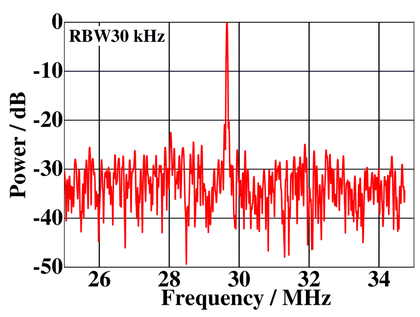


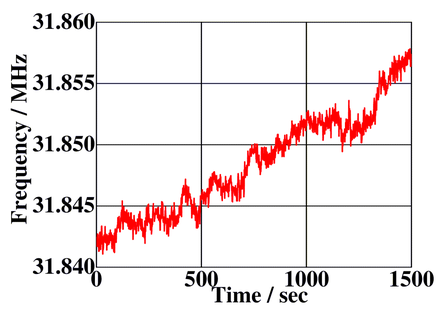
Gate time : 1s
Frequency fluctuation << 1 Hz
f_{CEO} locking maintaines over 2 Hours

Beat detection with CW laser



CW @871 nm
(Stabilized to high-finess cavity)





Beat frequency was read out by frequency counter.

Reference

[1] I. Inaba *et al.,* Opt. Exp **14**, 5223(2006).
[2] P. Wasylezyk *et.al.,* Opt. Exp **17**, 5631(2009).
[3] E. Mamoru *et.al.,* Opt. Exp **20**, 12191(2012).
[4] S. Meyer et al., Eur. Phys. J. D **48**, 19 (2008).
[5] S. Meyer et al., Appl. Phys. B **112**, 565 (2013).