Mode-locked fiber lasers

by: Khanh Kieu
Project #8: Mode-locked fiber laser

- Measure laser pulse train
- Measure output spectrum
- Measure laser pulse duration
- Observe phase-locked of laser modes

Mode-locked ring fiber laser
How does the laser work?

Pump

Active medium

HR mirror

OC

Laser output

$L = q^*\lambda/2$
Mode-locking

Pump

HR mirror

Saturable absorber

Active medium

OC

Laser output

SA transmission curve

Locked phases of all laser modes

in phase!

out of phase

out of phase

Locked phases

Ultrashort pulse!!

Time

Intensity

Transmission
Mode-locking

Credit: Oscar Herrera
Time domain vs. frequency domain

Connected by the Fourier transform

Long pulse

Short pulse
Interesting facts about mode-locked lasers

Mode-locked lasers do not “work” 99.9999% of the time!

Mode-locked lasers generate the highest peak power among lasers

Mode-locked lasers provide one of the shortest events in nature

Mode-locked lasers are one of the best frequency rulers

Mode-locked lasers have the lowest timing jitter compared with most elec. devices
What is the best approach for mode-locking?

- Kerr lens (does not work for fiber, yet)
- Nonlinear Polarization Evolution (NPE)
- SESAM
- Carbon nanotubes (CNT) and graphene
Carbon nanotube saturable absorber

- ~1nm diameter
- Possess ultrafast carrier recovery time (<1ps)
- Robust
- Low cost

Great material for making saturable absorber!


Early implementations

(source: Set et al., Quant. Elect., 2004)

Drawbacks:

• Not fiber compatible

• Thin film geometry: very low damage threshold
Fiber taper based CNT SA

Fiber taper-based CNT SA


Carbon nanotube bundles

Fiber taper (top) and standard fiber (bottom)

First battery operated femtosecond fiber laser in the market
Compact ML fiber laser

- Fiber taper with SWCNTs
- Erbium doped fiber
- 980/1550nm WDM fiber coupler
- Laser output

Graphs and diagrams showing signal amplitudes, delay times, FWHM bandwidth, and output power over time at different temperatures in Fahrenheit.
Autocorrelation measurement

- Input pulse train
- 50/50 Beam-splitter
- Focusing lens
- Corner cube
- Delay line
- BBO crystal
- Silicon photodetector
- Oscilloscope

1 ps
Amplified pulses at ~ 1550nm

Fiber taper embedded in CNT/polymer composite

100 mW average output
100 MHz repetition rate
compressed to ~ 65 fs with SMF28
Peak power > 10kW
Supercontinuum generation

ML laser → EDFA → HNLF

Octave spanning SC in 3 cm of HNLF!

K. Kieu et al., PTL. 2010
Few cycle pulse generation

K. Kieu et al., PTL. 2010
Multiphoton imaging

- 3D sectioning
- Non-invasive
- High resolution
- Chemical sensitivity (CARS)

W. Zipfel et al., nature 2003
500 µm into mouse cortex, where the soma of layer 5 pyramidal neurons are clearly visible surrounded by capillary beds (scale bars are 75 µm)
Brain Imaging

(Collaboration with C. Barns, S. Cohen, A. Koshy, L. Madhavan)

• Label-free identification of cell type
• Match behaviors to corresponding cells
• Stem cell imaging
• Parasite tracking
• Rapid whole brain imaging
• and more…

Blue: YFP
Red: Endogenous

2mm
Brain Imaging

(Collaboration with C. Barns, S. Cohen, A. Koshy, L. Madhavan)

Blue: YFP
Red: Endogenous

200µm
Brain Imaging
Whole body 3D imaging of small insects
Questions for thoughts

• Can fiber lasers be used for all applications?
  (Think of an application that current fiber lasers cannot be used)

• What is the power limit of fiber lasers?

• Is that important to know exactly who invented the laser?

• How many more years are we going to do research on lasers?

• Can we use lasers to predict earthquakes?