




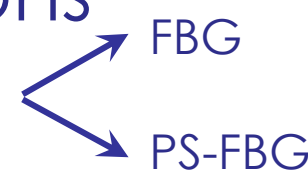
Single-mode Er-doped fiber lasers

**Rosa Ana Perez-Herrera and
Prof. Dr. Manuel Lopez-Amo**



**Public University of Navarra
Universidad Publica de Navarra**

INDEX

- 1_ Laser cavity resonance modes
- 2_ Cavity Er-doped fiber laser configurations
- 3_ Short SLM **linear** cavity configurations
 - Single wavelength
 - Double wavelength based on 
 - pairs of FBG
 - superposed-FBG
- 4_ SLM **ring** cavity configurations
 - Dual-wavelength EDRFLs based on 
 - FBG
 - PS-FBG
- 5_ Conclusions

INDEX

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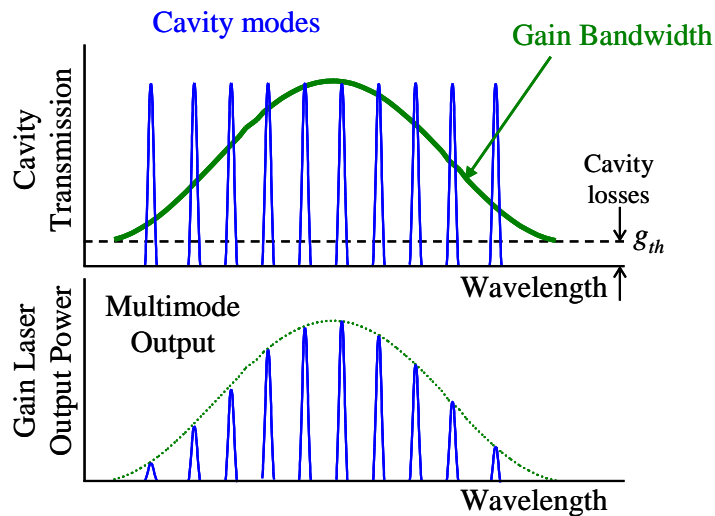
4_ SLM **ring** cavity configurations

- Dual-wavelength EDRFLs based on

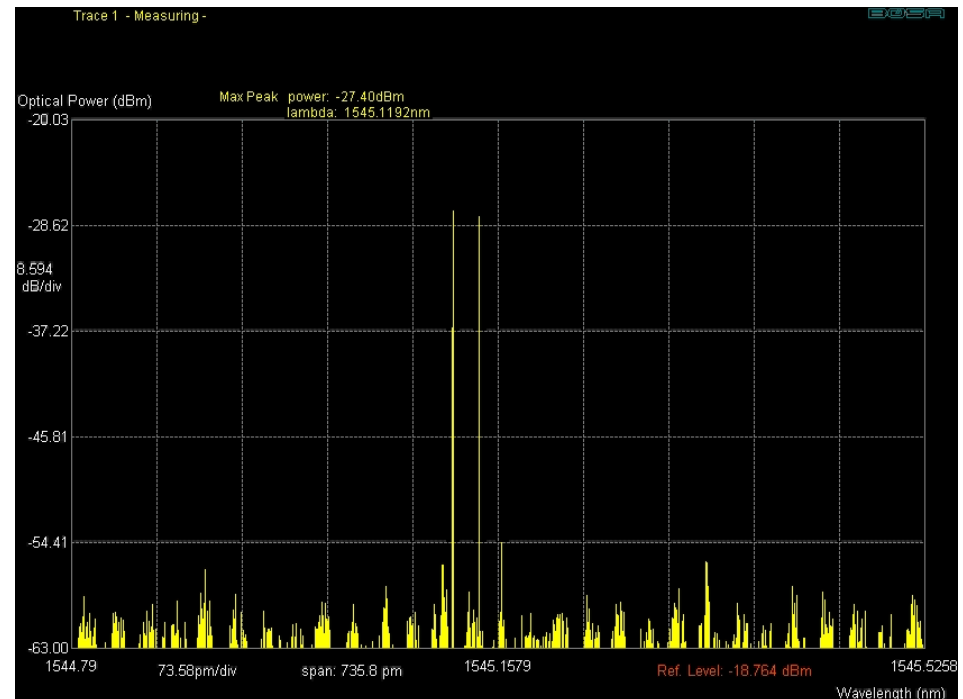


5_ Conclusions

1 Laser cavity resonance modes



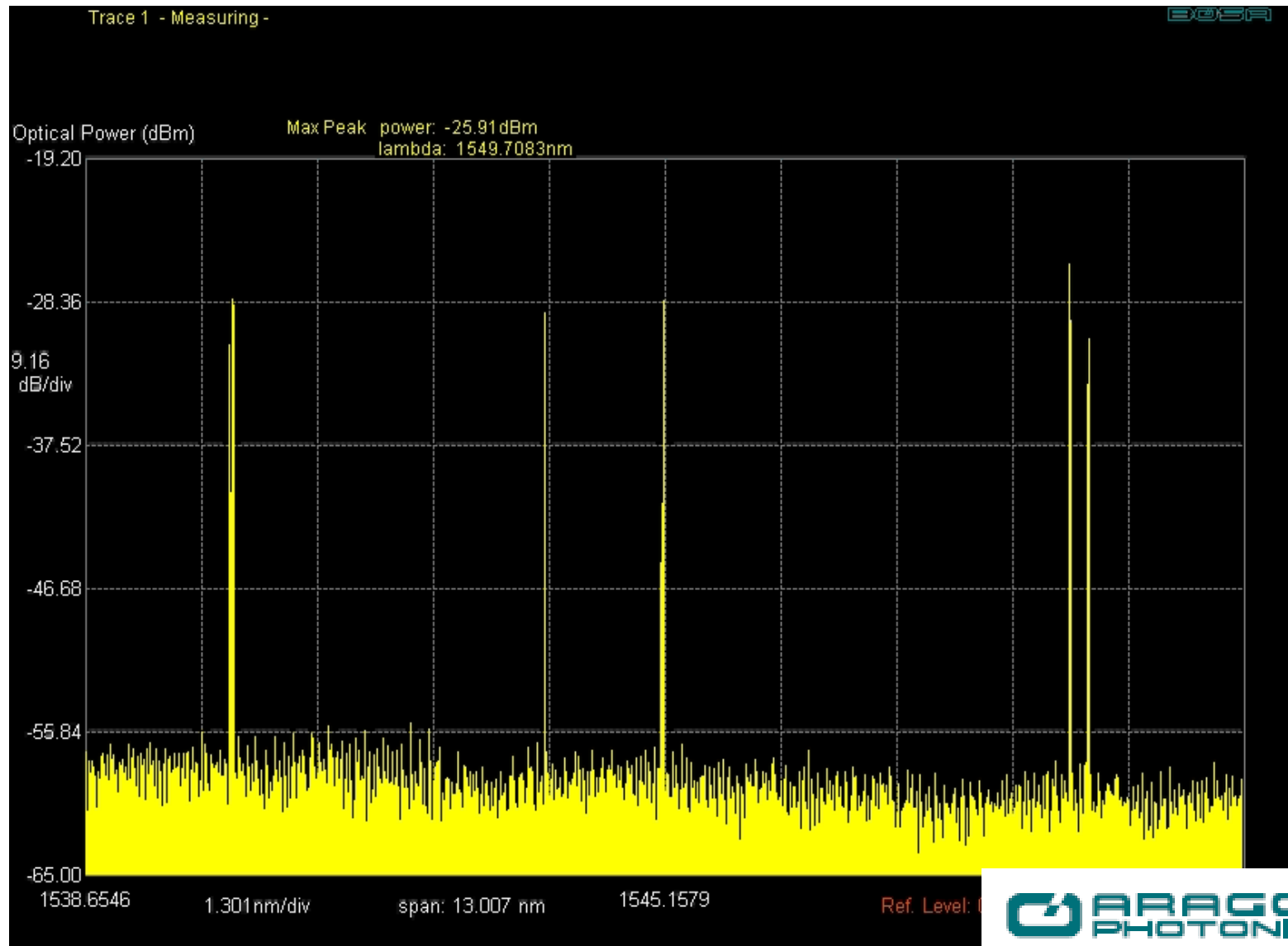
Cavity resonance modes that fit within the gain bandwidth



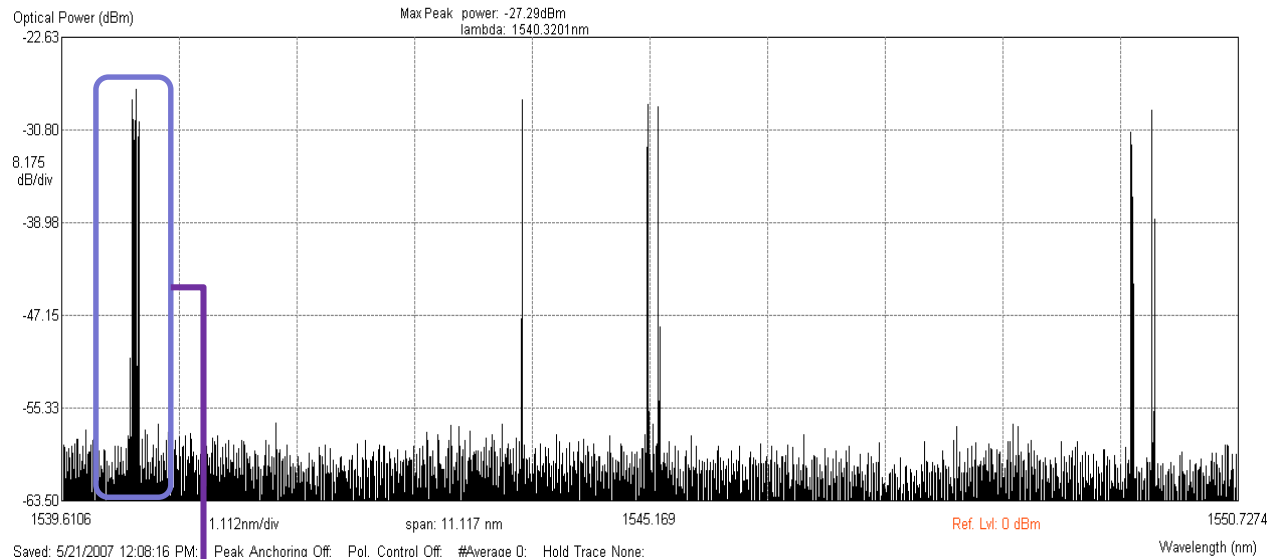
Output spectrum of an optical fiber ring laser (BOSA)

- **BOSA technology:** Stimulated Brillouin Scattering and relies on a pure optical analysis for the SUT transmitted through a nonlinear medium stimulated by a tunable laser source (TLS)
- To obtain single-mode laser radiation: a frequency dependent loss element (a filter) to insure that gain is higher than loss for only **one single longitudinal mode** (SLM)

BOSA Technology



BOSA Technology



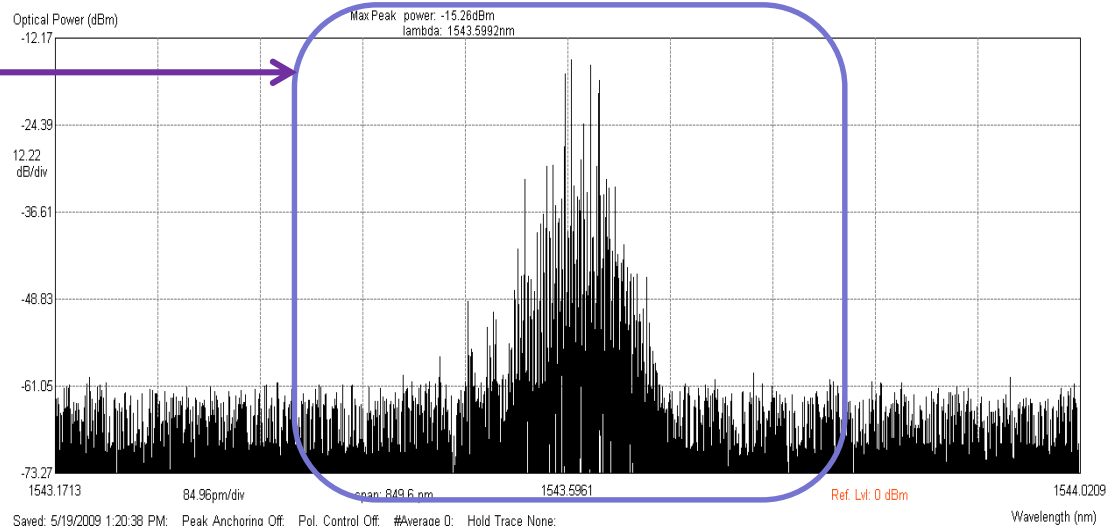
Output power spectrum for an EDFRL in a star topology

RESOLUTION

0.08pm (10MHz @ 1550nm) resolution

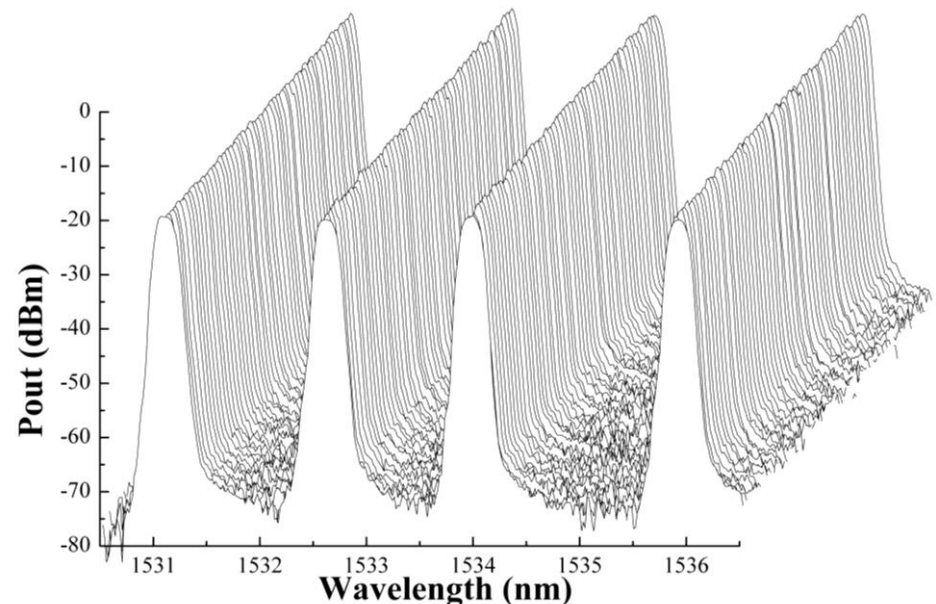
80dB dynamic range

upna



Laser output fluctuations

- can significantly degrade the performance characteristics of a sensor array based on a tunable ring laser interrogation scheme
- systematically effort to study their causes, optimization of:
 - pump power
 - doped fiber length
 - ions concentration
 - output coupling ratio
 - total cavity length
 - spectral hole-burning effect
 - the cavity loss



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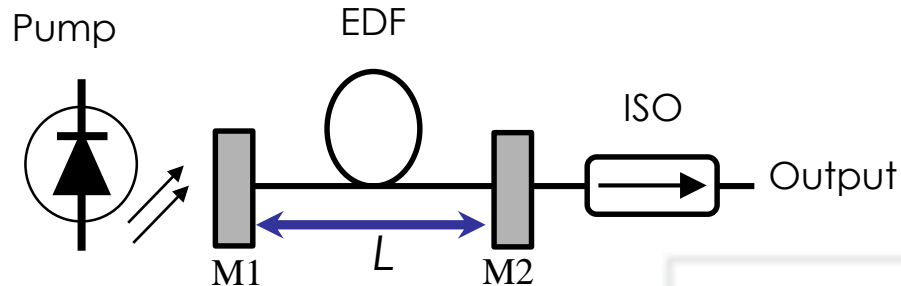


5_ Conclusions

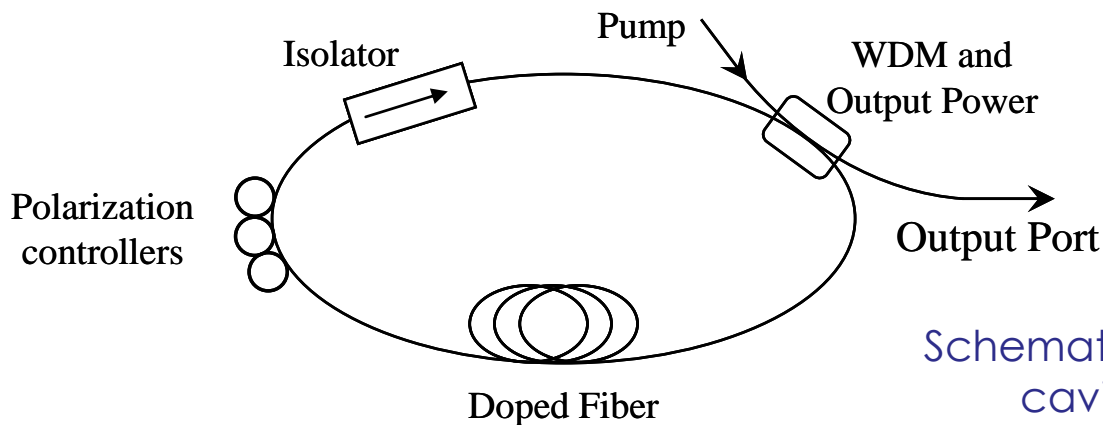
2 Cavity Er-doped fiber lasers

- Linear cavity EDFL

General schematic diagram of a linear cavity EDFL



- Ring cavity lasers


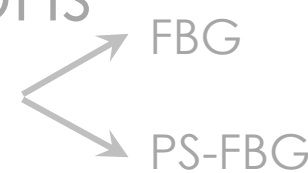


$$\Delta\lambda = \frac{\lambda^2}{n \cdot 2L}$$

$$\Delta\lambda = \frac{\lambda^2}{n \cdot L}$$

Schematic of a unidirectional ring cavity used for fiber lasers

INDEX

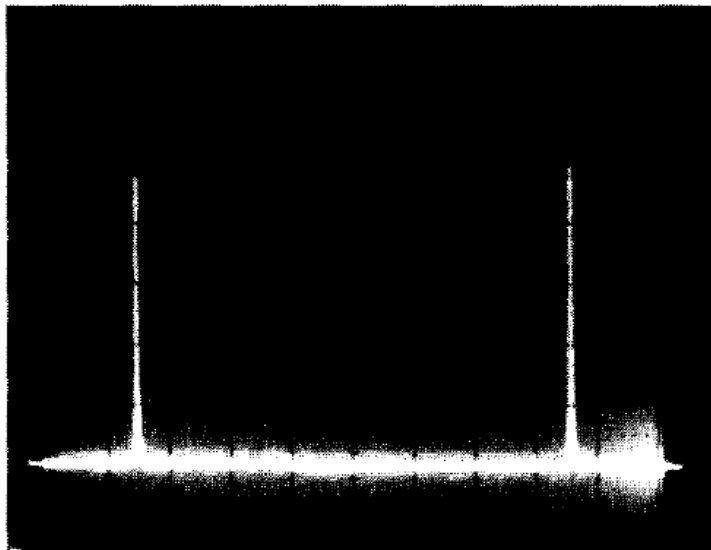
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3 Short single frequency EDFL

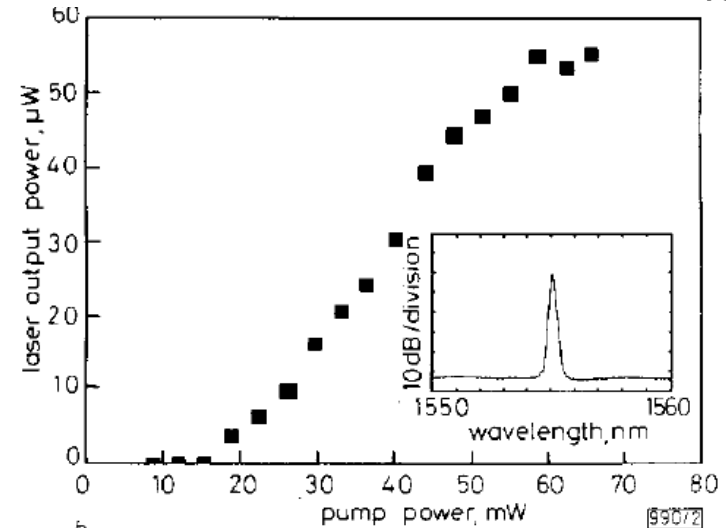
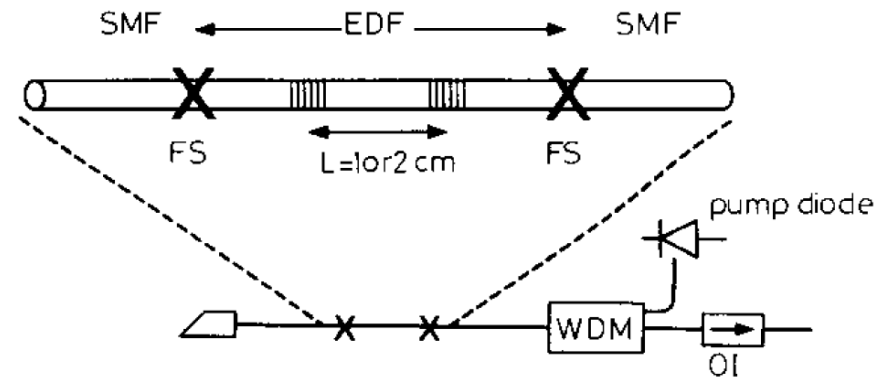
Short erbium-doped fibre laser
with holographically written DBRs

Very short lasers robustly single-mode

Fabry-Perot etalon scan of laser output
showing one full free spectral range of
17.3GHz



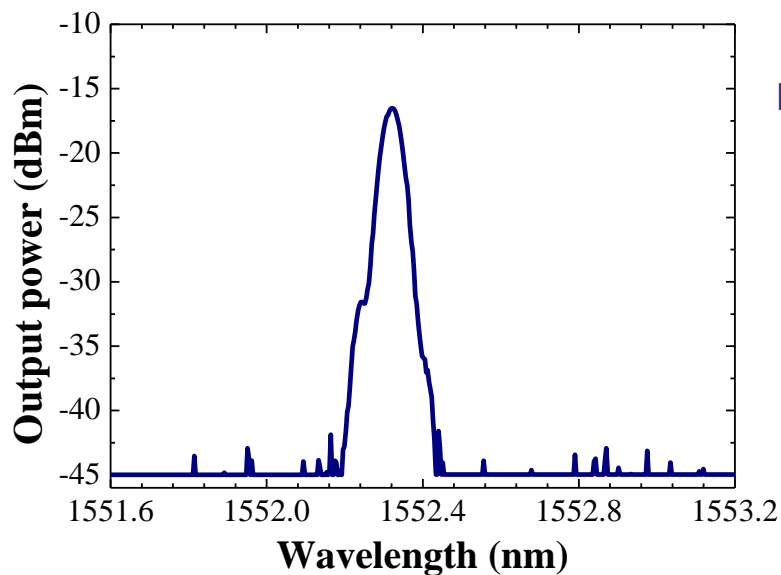
2.4GHz/division



Laser output as function of pump power for a
fiber laser with 2 cm cavity and for 1 cm laser

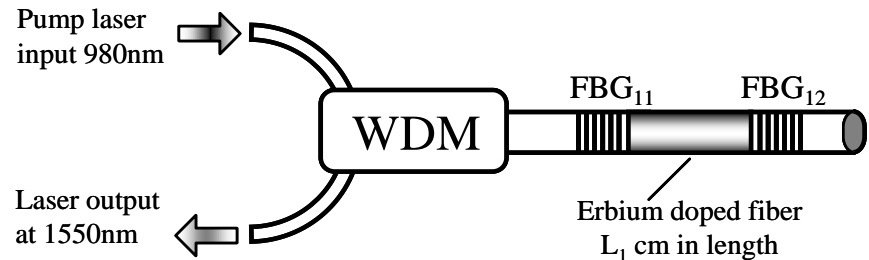
Short Linear cavity EDFL

- Single wavelength fiber laser

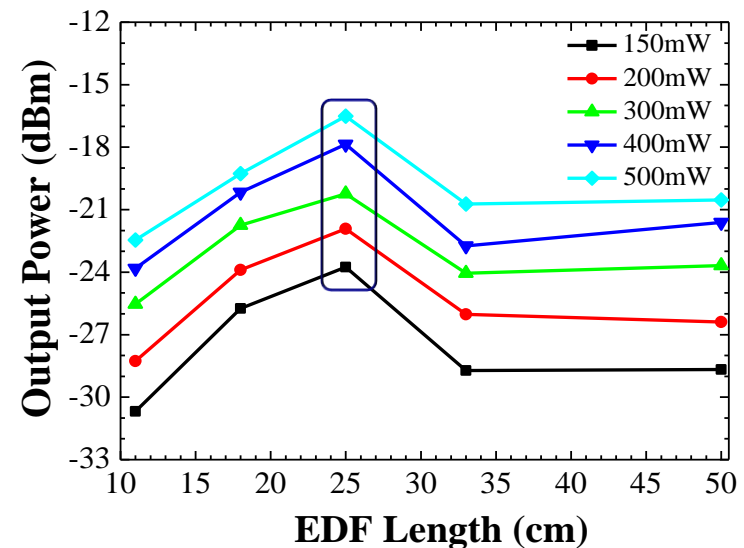


Laser spectrum generated by the SCL (25cm of EDF pumped by a 500mW)

An optimal length of gain medium exists for each specific doped fiber

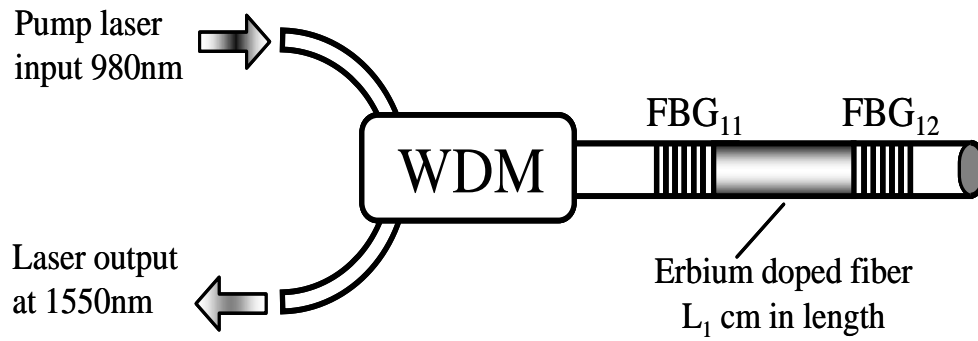


Experimental setup of a linear short cavity fiber laser

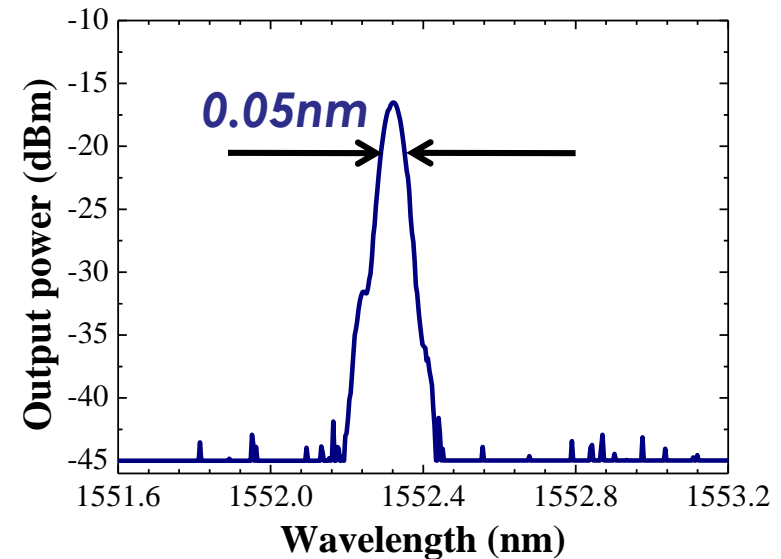


Laser output power changes as a function of EDF length and pump power

Number of modes inside the SCL



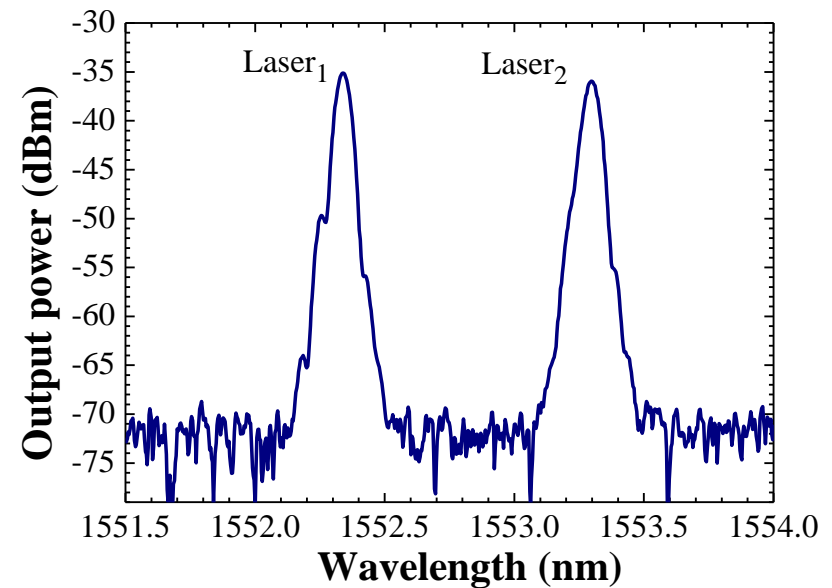
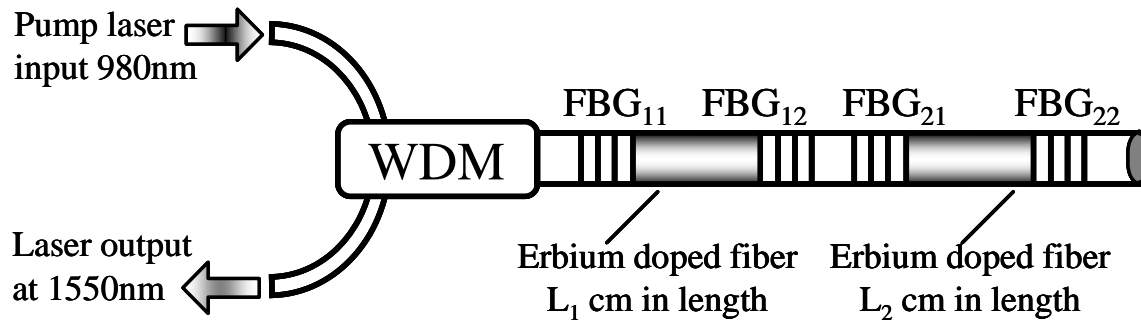
Experimental setup of a linear short cavity fiber laser



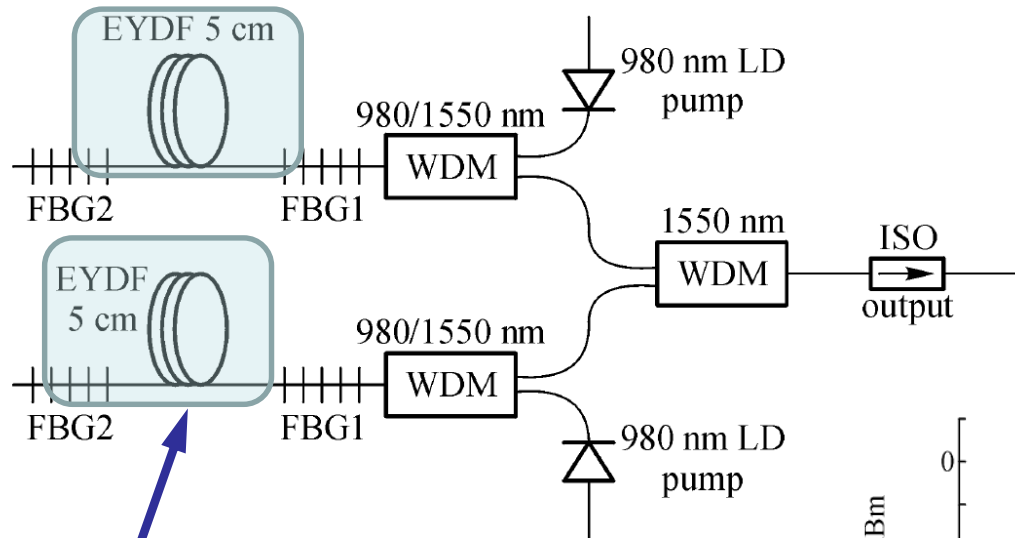
$$\Delta\lambda = \frac{\lambda^2}{nL} = \frac{(1550 \cdot 10^{-9})^2}{1.5 \cdot 0.25} = 6.42 \cdot 10^{-3} \text{ pm is the mode spacing}$$

$$N = \frac{FWHM}{\Delta\lambda} = \frac{0.05 \text{ nm}}{6.42 \cdot 10^{-3} \text{ pm}} = 7.7 \approx 8 \text{ modes inside the SCL when 25cm of Er-80 were use}$$

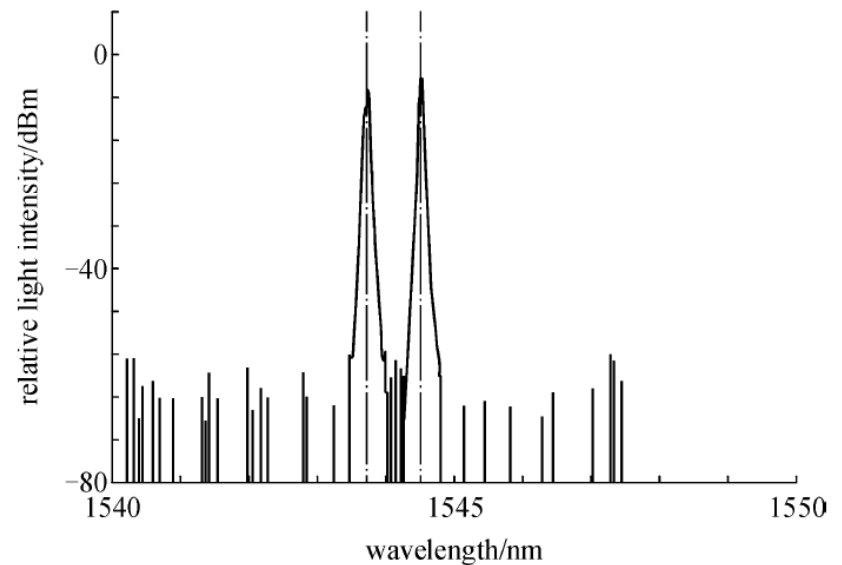
Double wavelength fiber laser



Double wavelength fiber laser

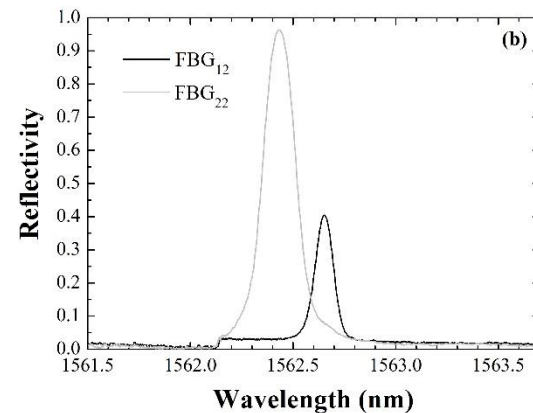
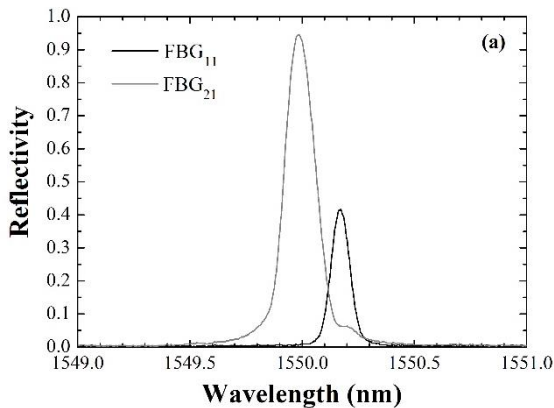
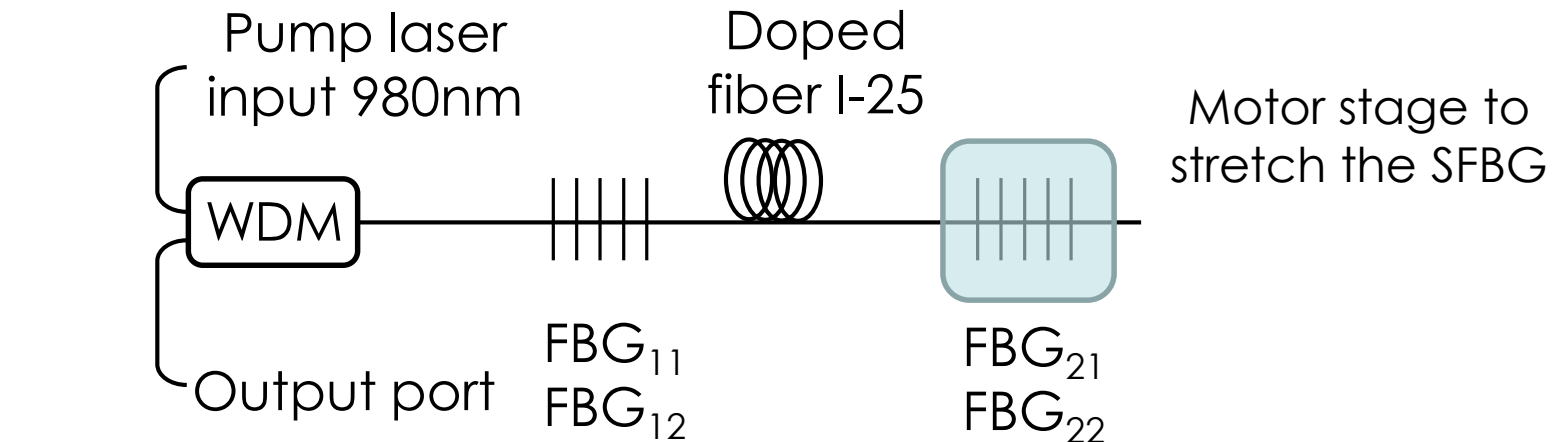


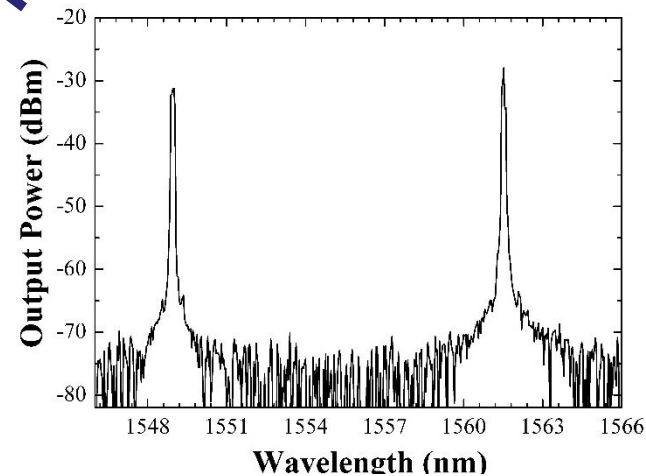
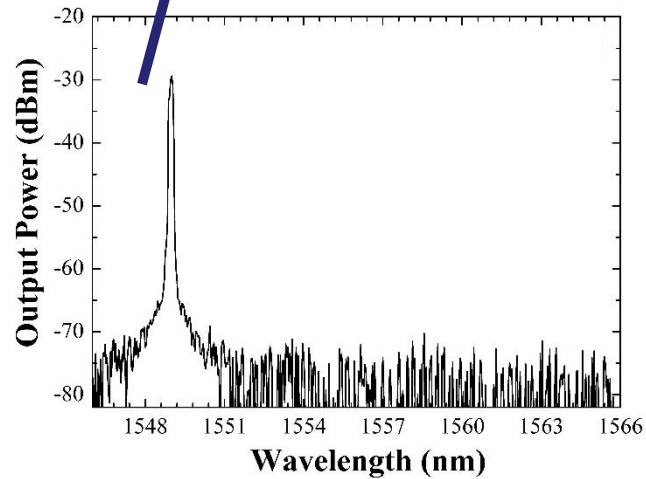
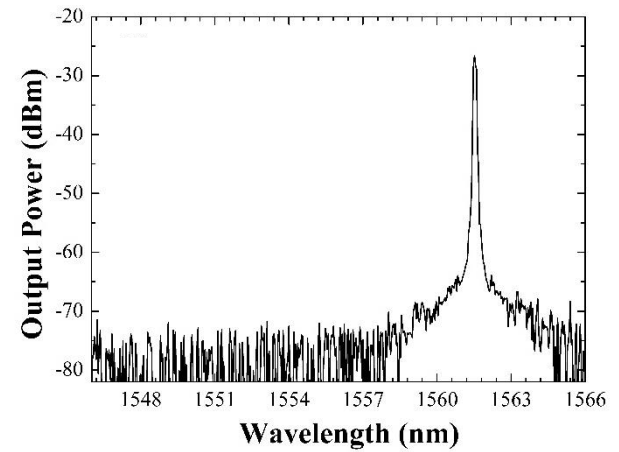
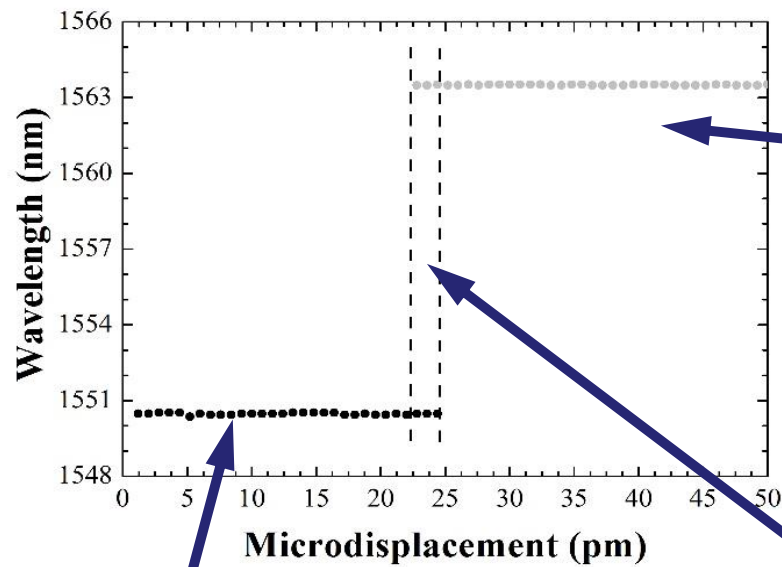
not only erbium but
also ytterbium

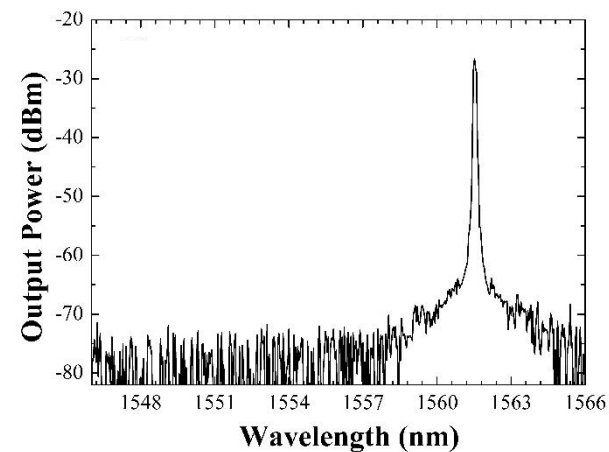
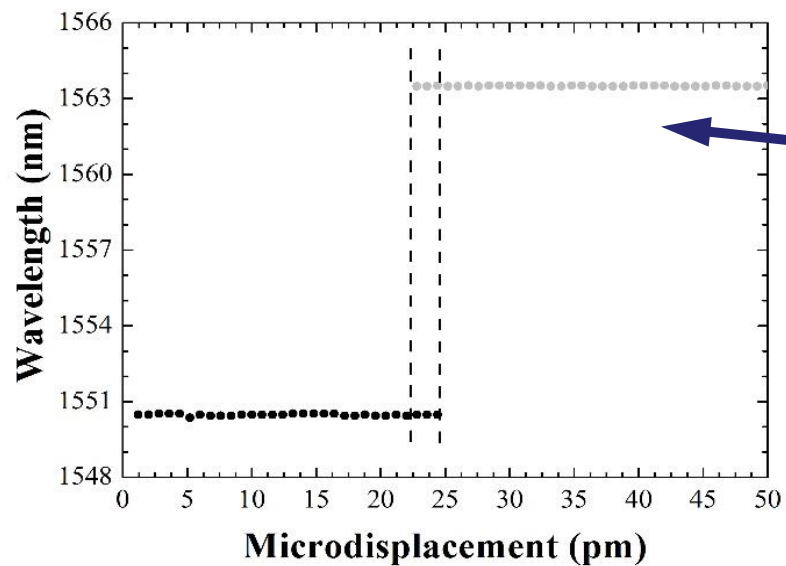


SLM dual wavelength-switchable fiber laser based on superposed FBG

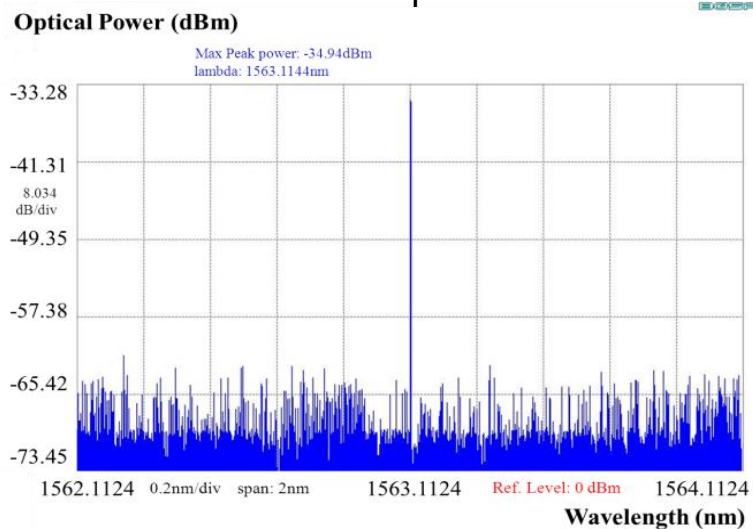
Linear and short cavity lasers



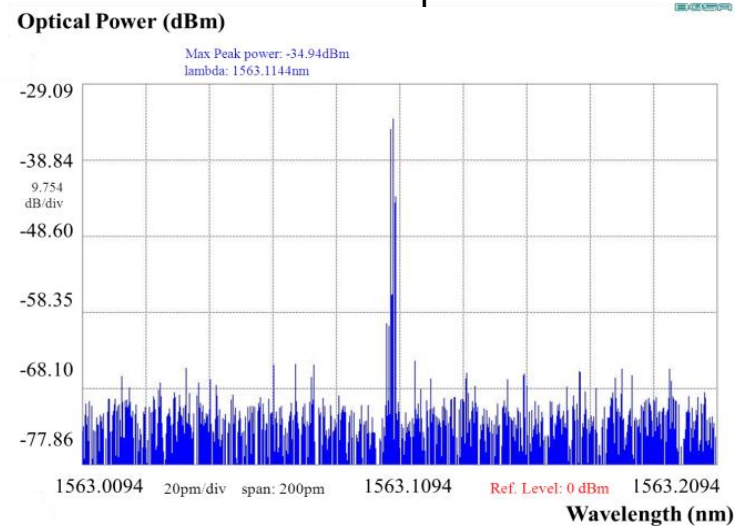





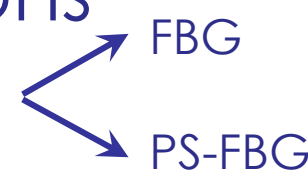
SLM operation



MLM operation



INDEX

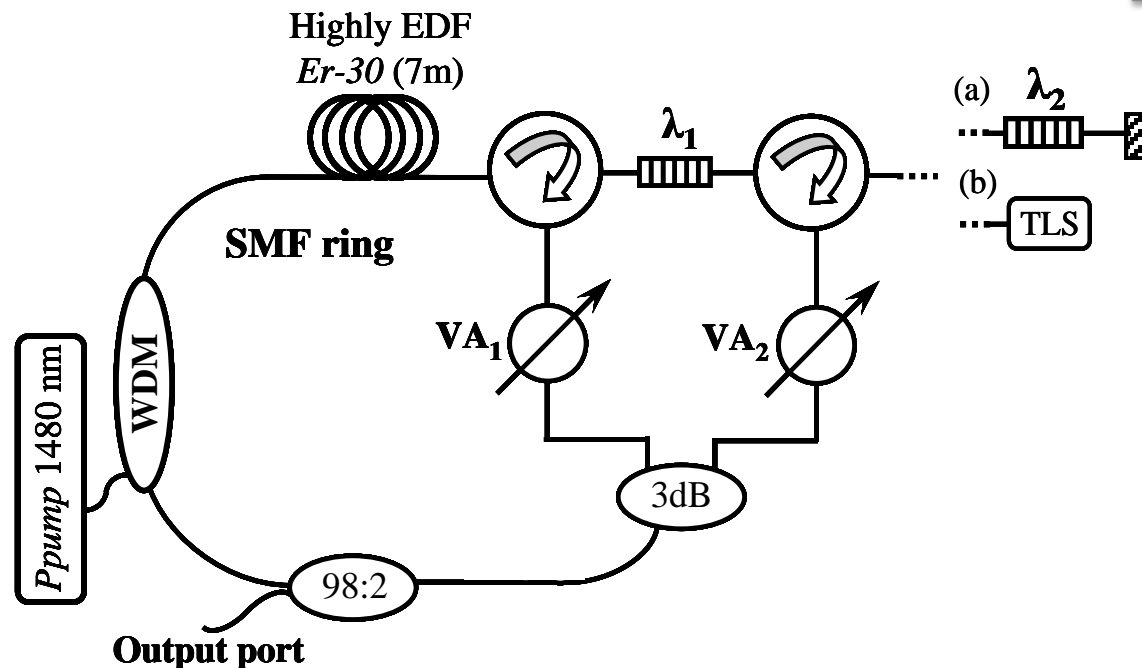
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4 Stabilization of dual-wavelength EDFRLs operating in SLM condition

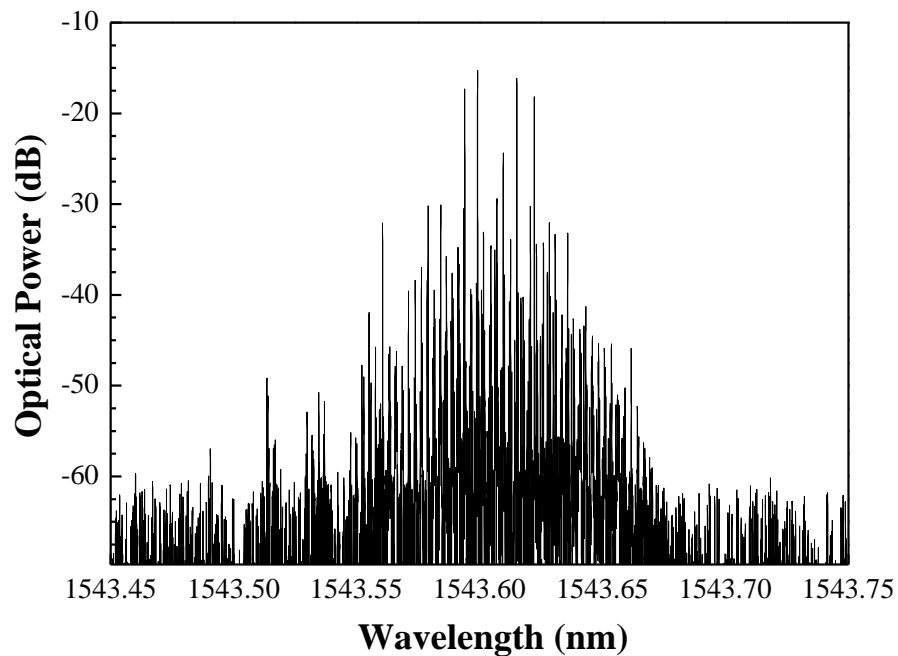
- EDFRLs usually generate multiple longitudinal modes around the central lasing wavelength due to its long cavity length
- Can limit their practical applications because of

mode competition

mode hopping



Experimental setup of the EDFRL using a serial topology (a) by using two FBGs and (b) by using and an external source (TLS: tunable laser source)



- Single-wavelength operation

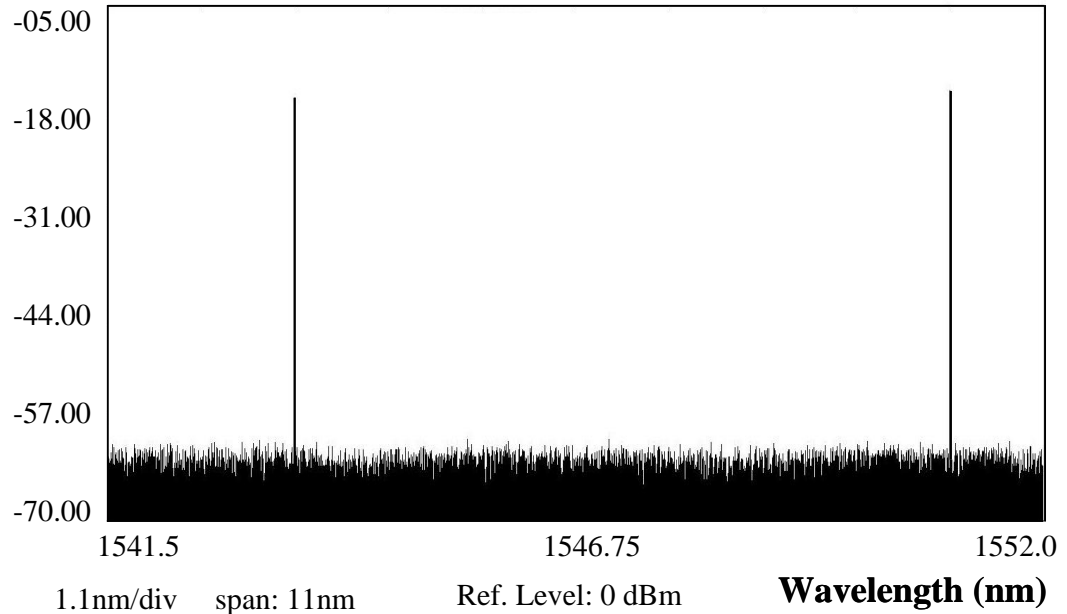
Multiple longitudinal modes are supported by the cavity

- Dual-wavelength operation

Single longitudinal mode (SLM) operation condition in both channels

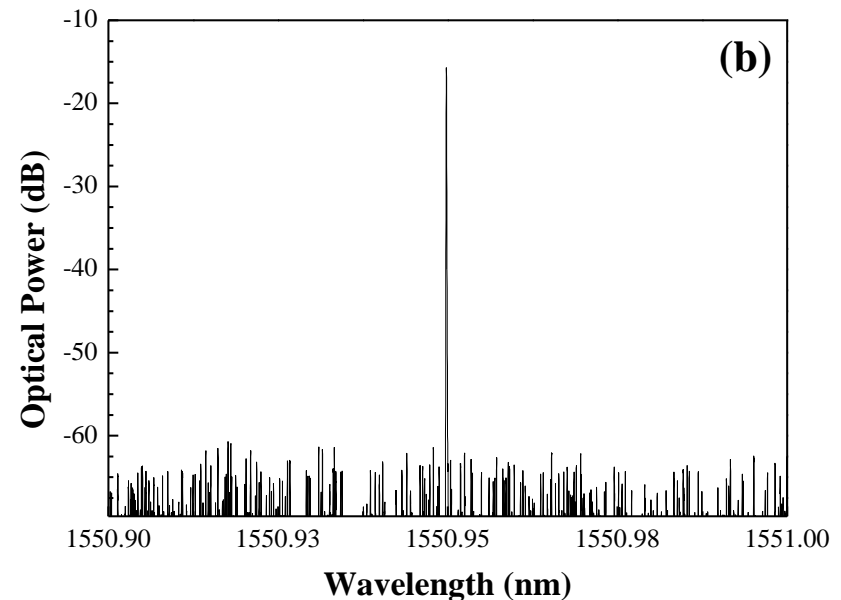
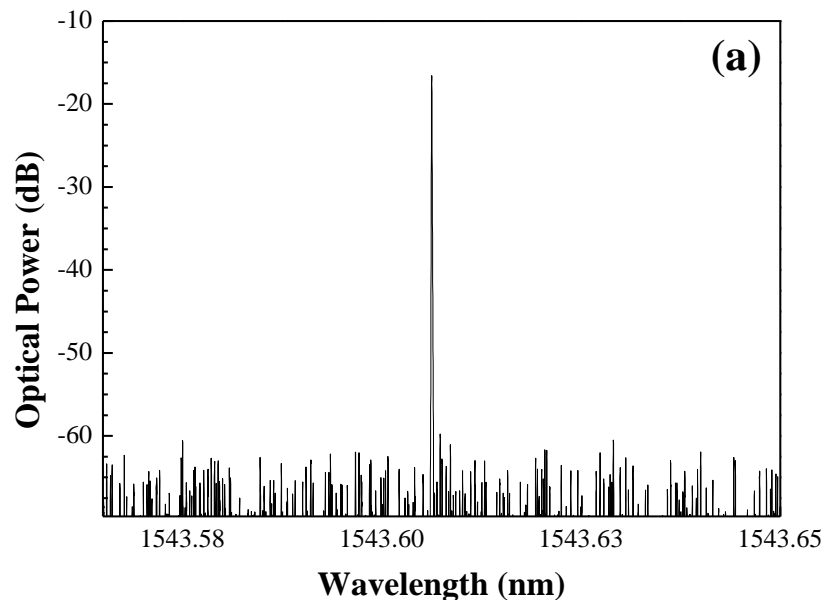
Optical Power (dBm)

Max Peak power: -15.72dBm
lambda: 1550.9498nm



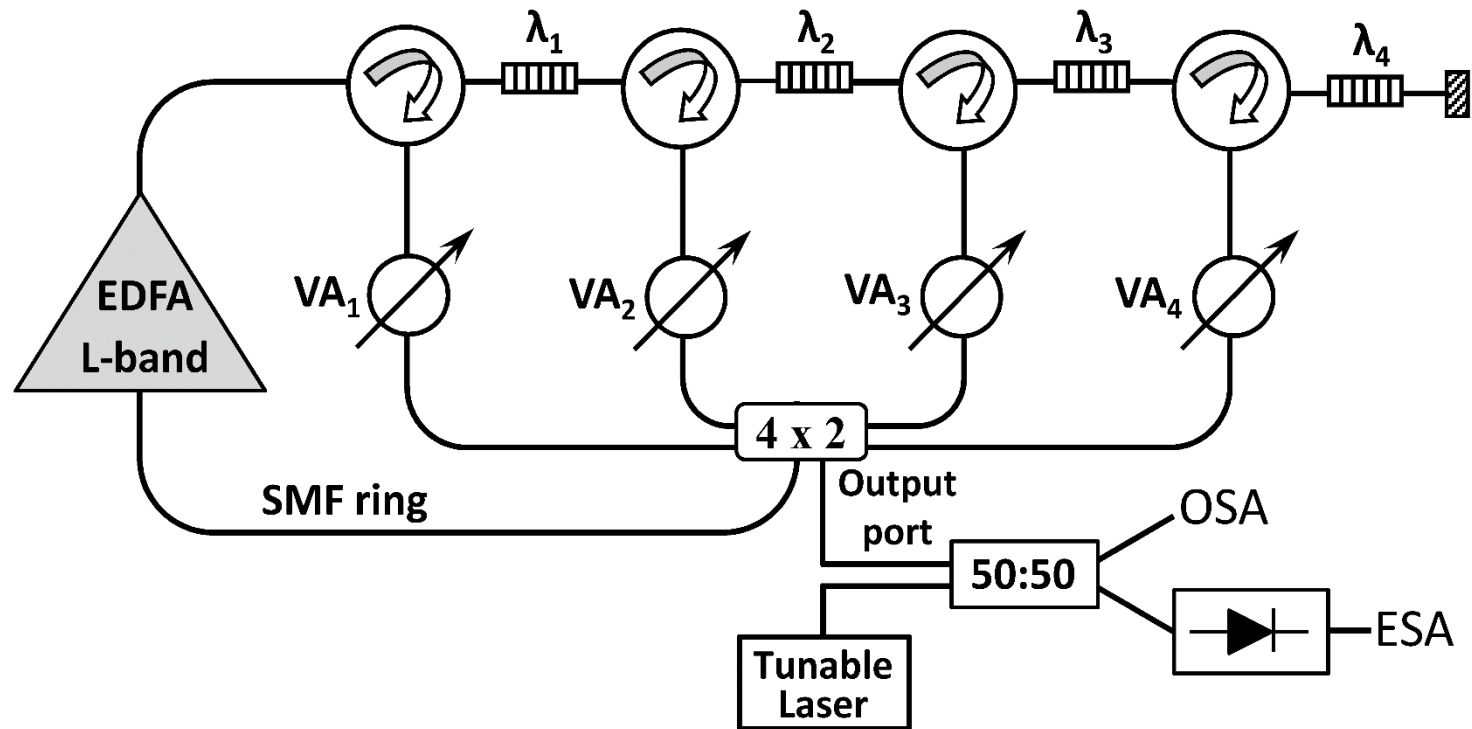
Dual-wavelength operation

Detail of the output spectrum (a) for the first channel ($\lambda_1 = 1543.6$ nm) and (b) for the second channel ($\lambda_2 = 1550.9$ nm) at dual-wavelength operation

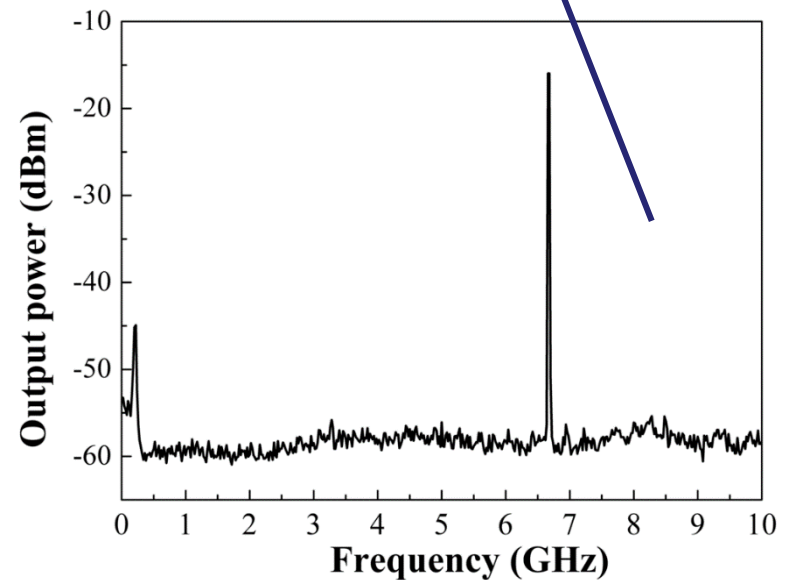
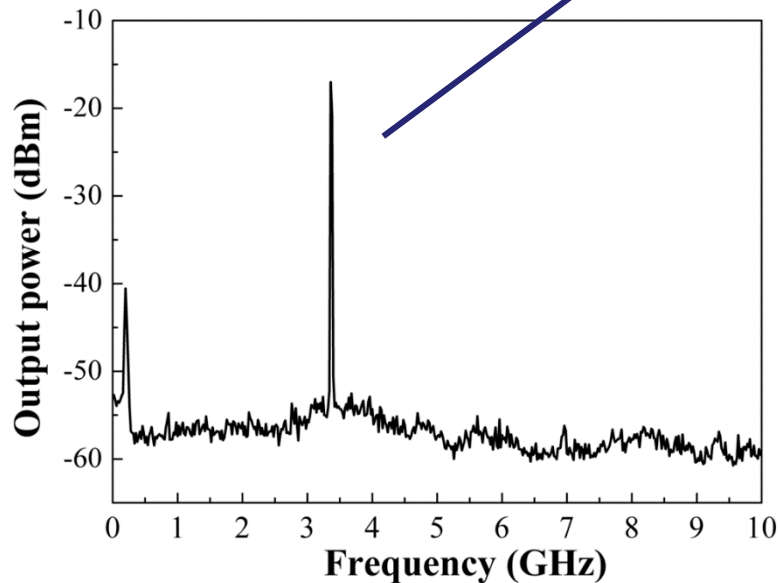
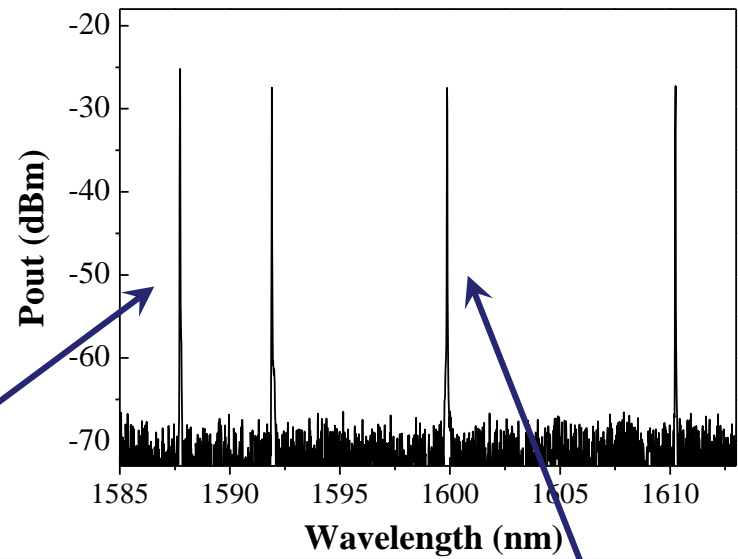


- These measurements have been repeated at different pump powers.
- In all cases, a SLM operation in both channels was achieved when the two lasing wavelengths are oscillating simultaneously with similar output powers

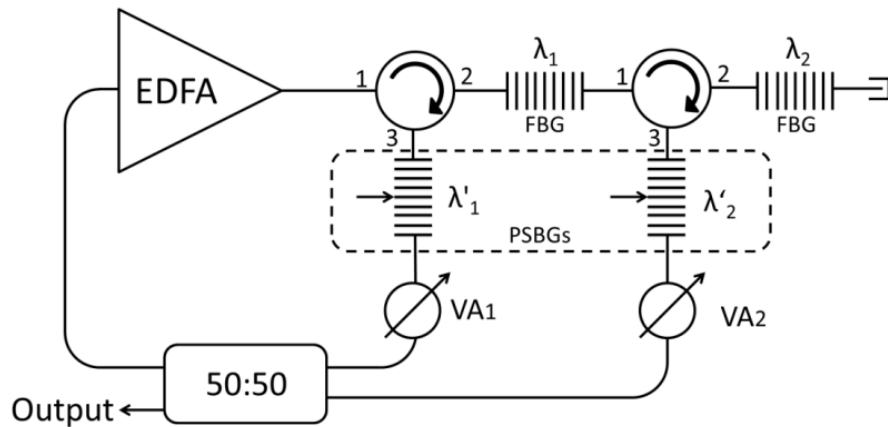
L-Band Multiwavelength SLM Fiber Laser



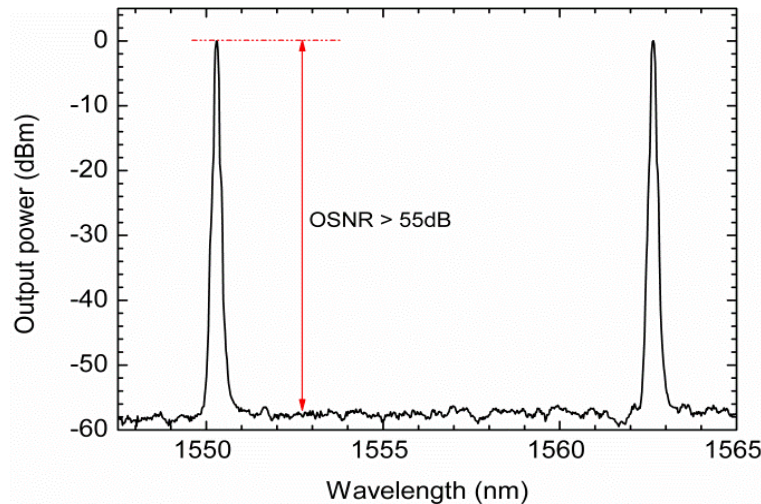
Output optical spectrum measured by the ESA for the MEDFRL circulators configuration when the tunable laser was tuned to the first and third wavelength laser emission.



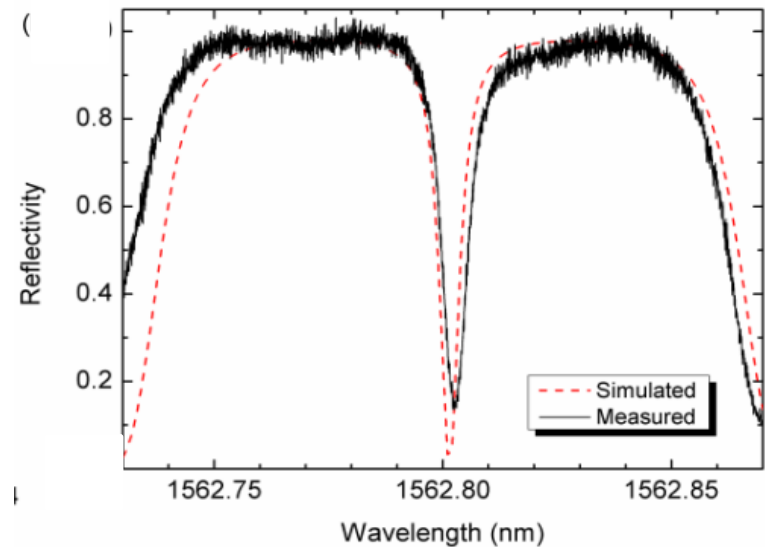
Dual-wavelength SLM EDFRL using PS-FBGs



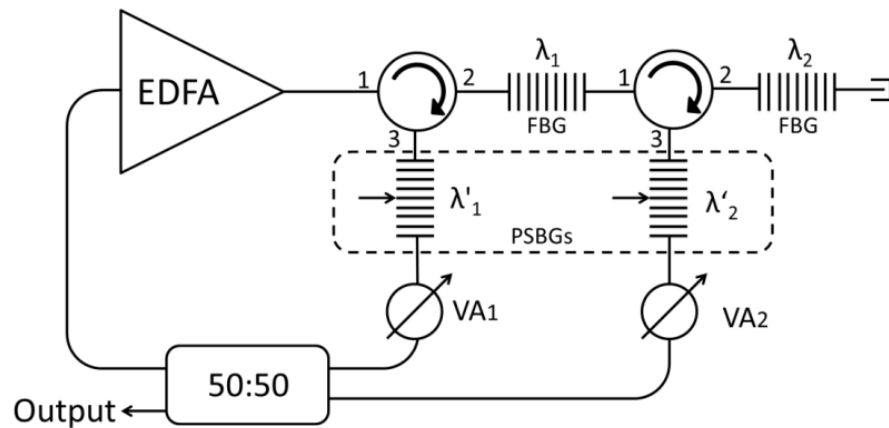
Output power at OSA



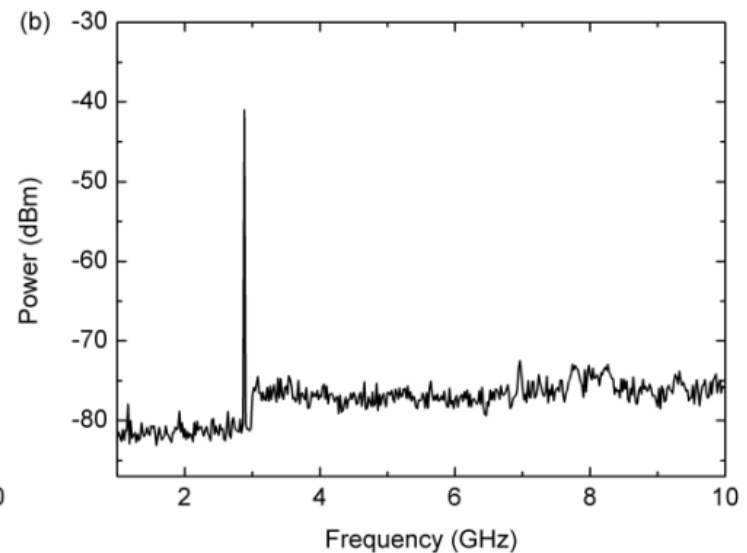
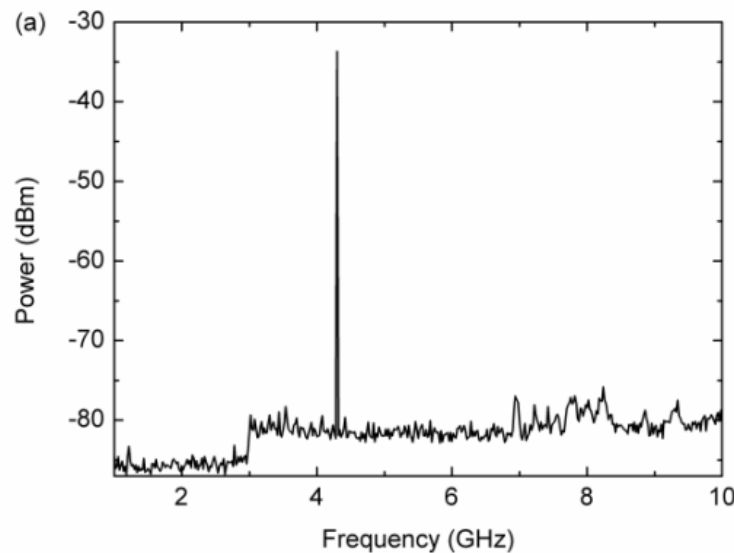
PS-FBG spectra




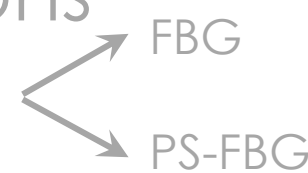
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SLM operation



INDEX

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6 Conclusions

- To obtain single-mode laser radiation: a frequency dependent loss element (a filter) to insure that gain is higher than loss for only **one single longitudinal mode** (SLM)
- Two cavity configurations: lineal and ring
- **Laser configuration** plays an **important role** to achieve stable multiwavelength lasing at room temperature
- **Very short lasers** are robustly single-mode
- A SLM operation in than one channel can be achieved when the lasing wavelengths are oscillating simultaneously under certain circumstances (with similar output powers)

Single-mode Er-doped fiber lasers

Thank you



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