Discrete Mode Laser Diodes emitting at λ~689 and 780nm for Optical Atomic clock applications.

Richard Phelan*, M. Gleeson, J. O'Carroll, D. Byrne, L. Maigyte, R. Lennox, K. Carney. J. Somers and B.Kelly

Eblana Photonics Ltd, Unit 32, Trinity Technology and Enterprise Campus, Dublin 2, Ireland

richard.phelan@eblanaphotonics.com

eblanaphotonics

www.eblanaphotonics.com

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Workshop on "Laser Diodes for Space Applications" • 4:00 PM, November 24th 2015
III-V Lab, Palaiseau Cedex, France.

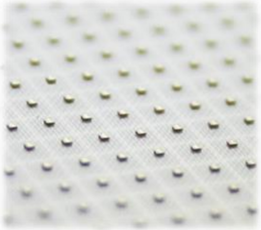
Talk Outline

- Eblana Company background
- Discrete mode laser diode technology overview
- Sr Optical clock transitions & laser requirements
- Characteristics Laser diode at λ~689nm
- Characteristics Laser diode at λ~780nm
- Narrow linewidth laser designs and results
- Summary

Company Background

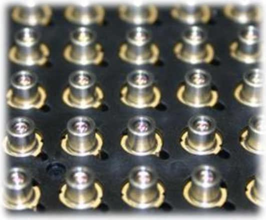
- Eblana established 2001 with the core technology developed at Tyndall Institute (Cork) and Trinity College Dublin
- Technology to deliver low cost, easy to manufacture single mode laser diodes for Fibre Optic Communications Market
- IP protection with over 15 patents
- Staff 15 and located in Dublin, Ireland.
- Market prominence established in Taiwan and China
- Eblana building volume shipments to 200,000 laser units per month
- Launched Specialty Laser business 2011 (lasers for Sensing applications)
  - Supplying laser diodes at wavelengths from λ~690, 760 ,780, 1877, 2004, 2051, 2300, 2400, 3300nm
- EU (FP7, Horizon 2020) / ESA / EI programs funding R&D activities

Laser Diode Packages



Bare Die

TOSA



TO-56

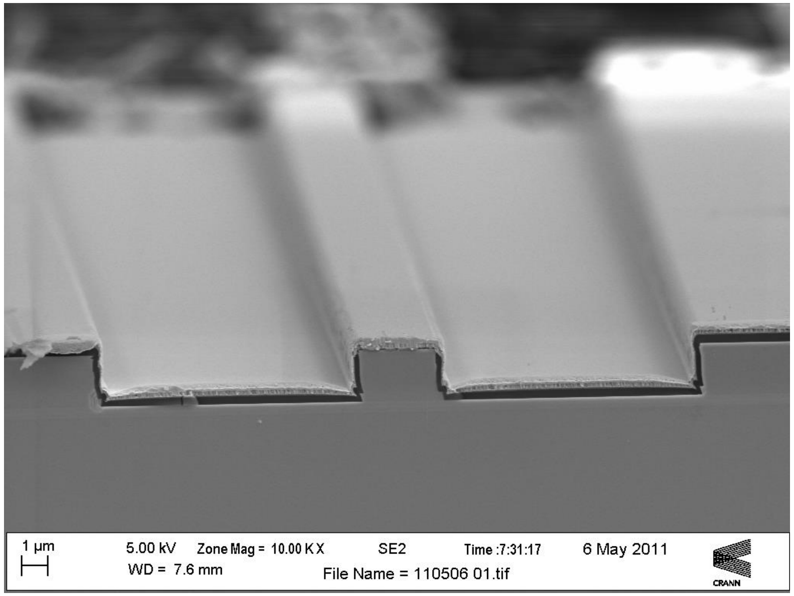
Coaxial Module

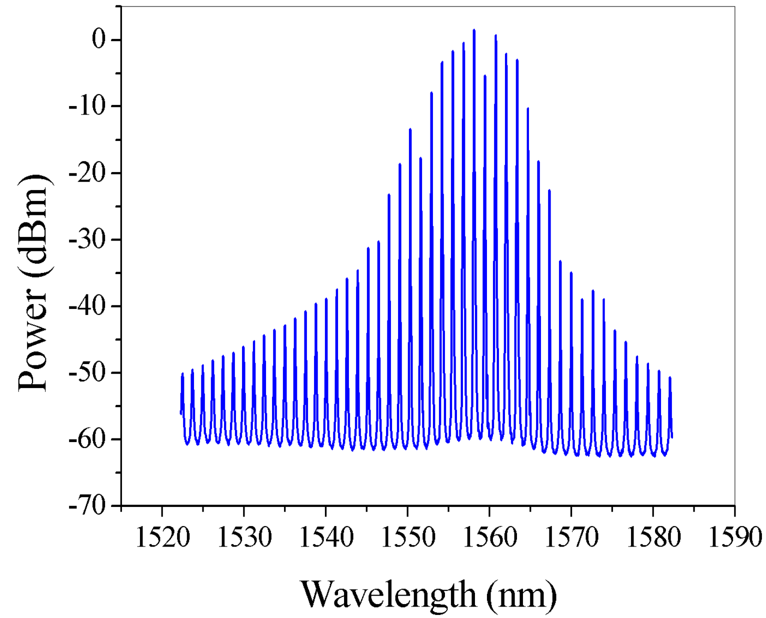
TO-9

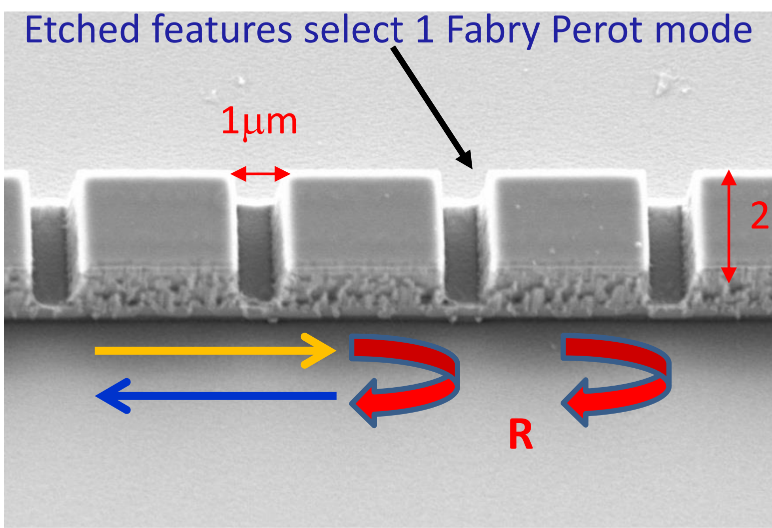
Butterfly Module

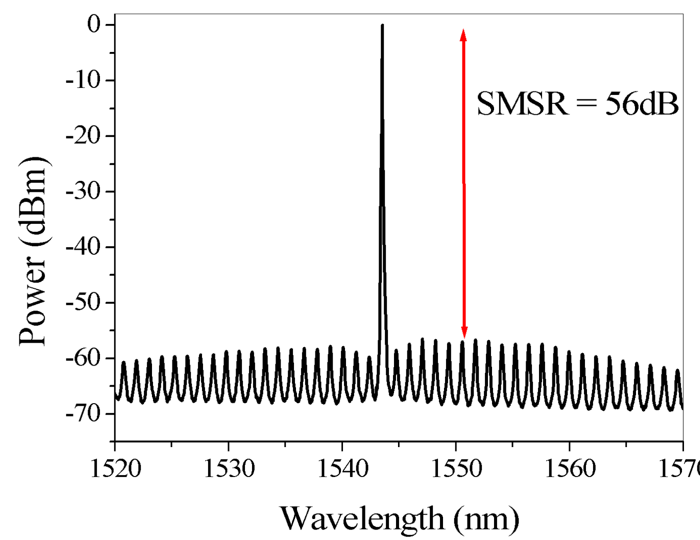
Discrete Mode Technology Overview

Discrete Mode Laser Diode Overview





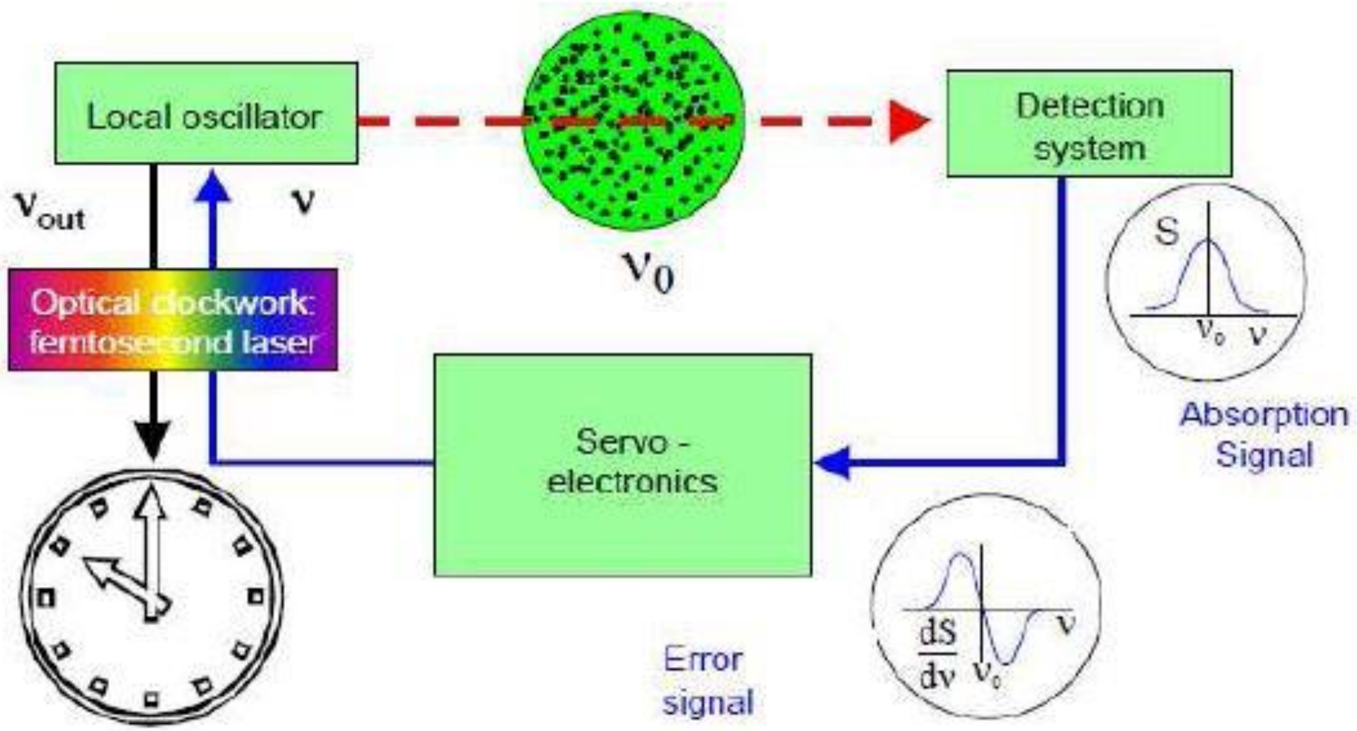




Discrete Mode Laser Diode ~ 689nm

ESA contract 4000112867/14/NL/CBi/fk

Optical clock Overview

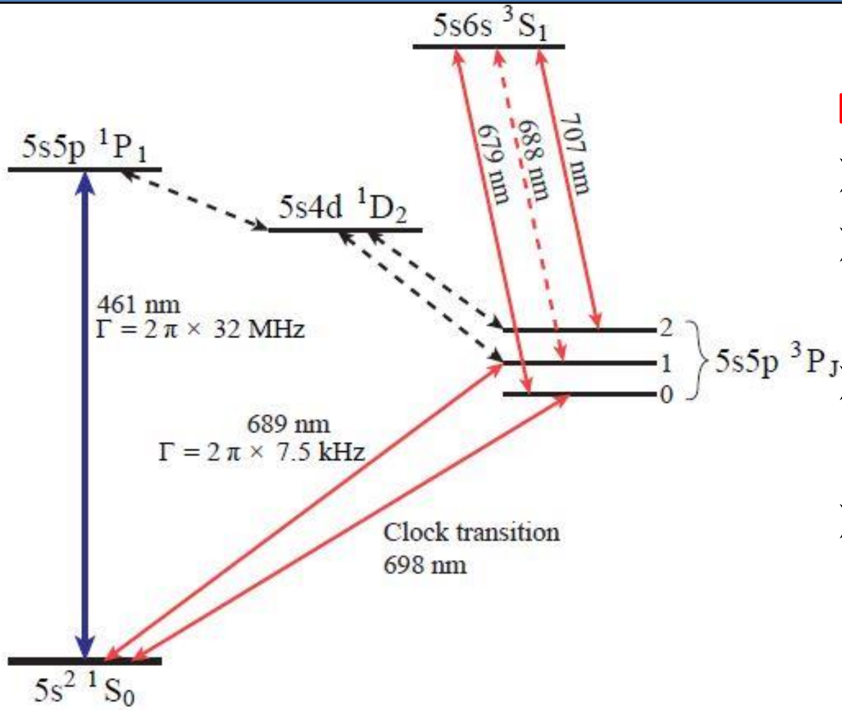


Optical Atomic Clock (OAC) block diagram

- Ultra narrow linewidth Laser
- An absorbing medium atoms, ions which has to be laser cooled and trapped
- Detection & Electronics to lock the laser to the transition
- Frequency comb to transfer to RF

Ref "Space Optical Clocks (SOC2)" (2007-2010) (www.spaceopticalclocks.org)

Sr Levels Relevant to the Clock



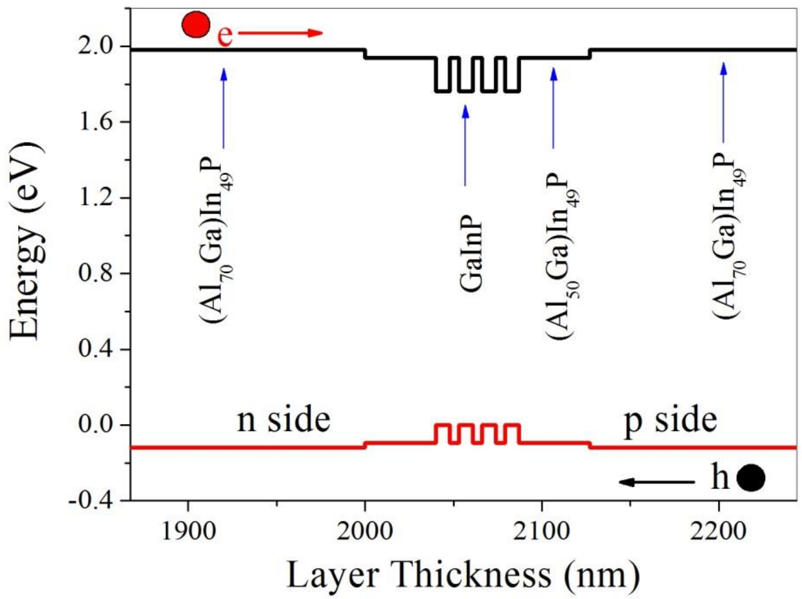
ESA motivation ~Optical clock in space

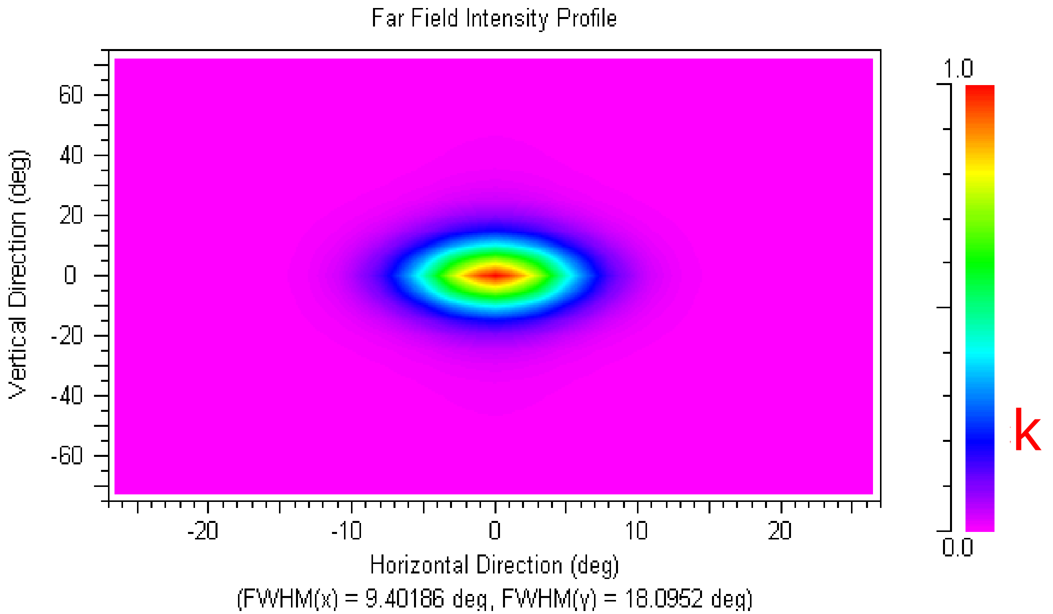
- Emphasize on and low-power consumption
- Use advanced miniature laser technologies and avoid frequency doubling (SHG) stages.
- Implement light propagation in optical fibers

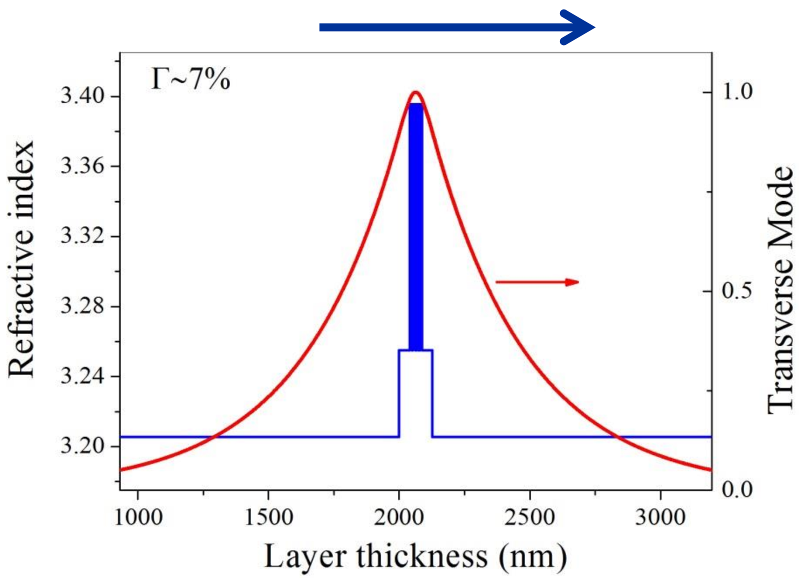
- Key laser parameters:
  1. Wavelength
  2. Power
  3. Linewidth

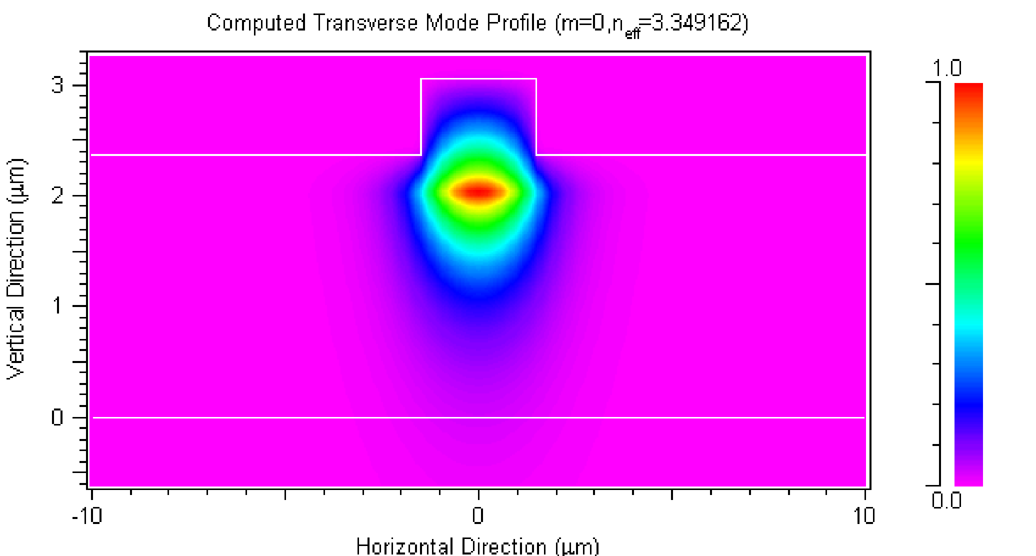
Laser Sub-system	Wavelength	Linewidth	Power
Sr Optical Lattice			
1st Stage Cooling Laser	**461 nm**	< 1MHz	150mW
2nd Stage Cooling	**689 nm**	< 1kHz	20mW
Repumper Laser No. 1	**679 nm**	< 100 MHz	10mW
Repumper Laser No. 2	**707 nm**	< 100 MHz	10mW
Clock Laser	**698 nm**	< 1 Hz	10mW

Laser emission at λ=689nm [Al(x)Ga]In(y)P material

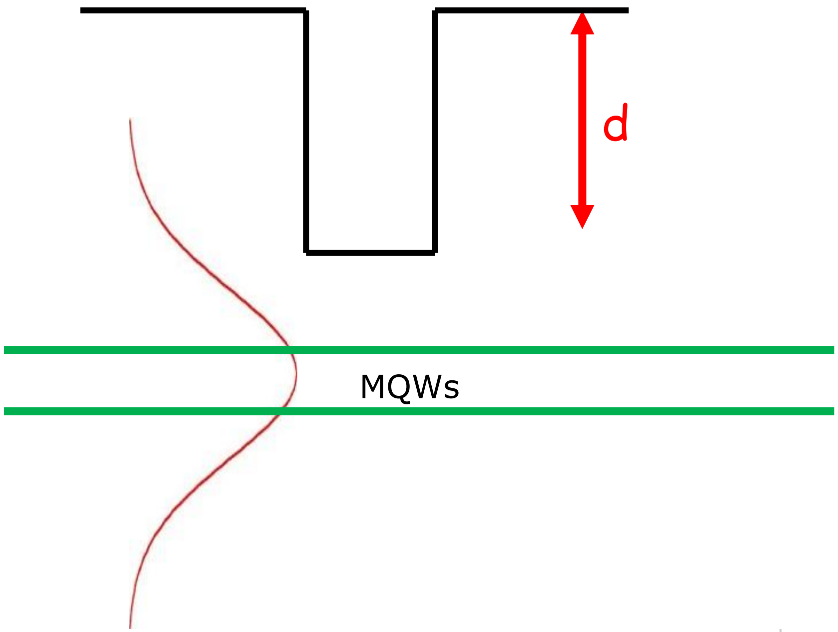


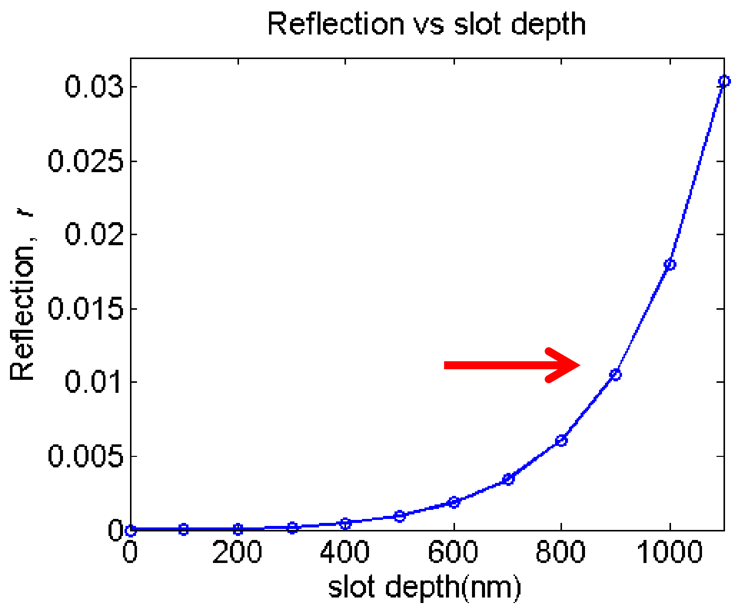


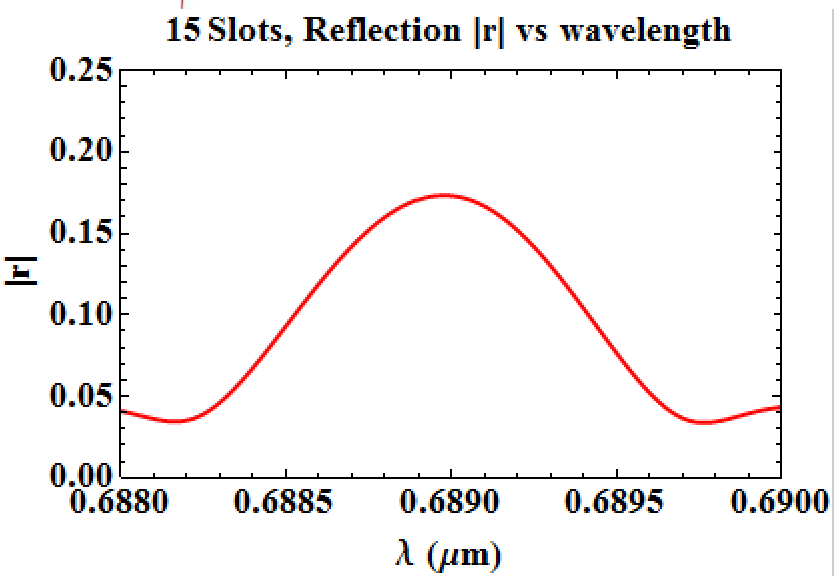


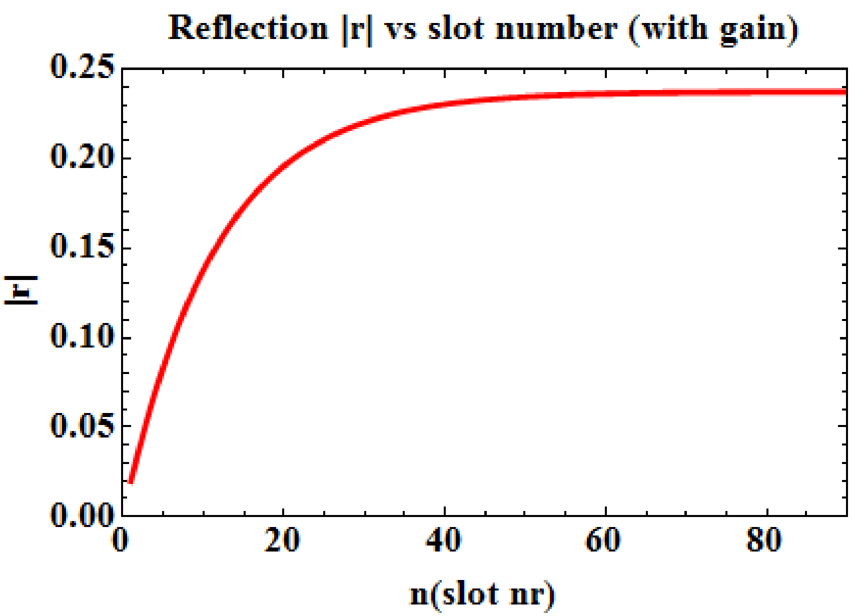


Grating Design

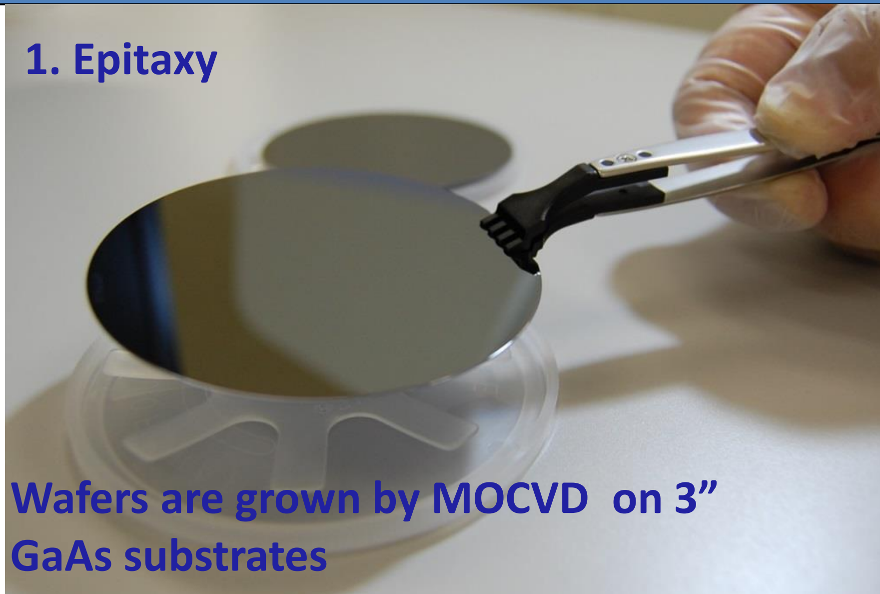


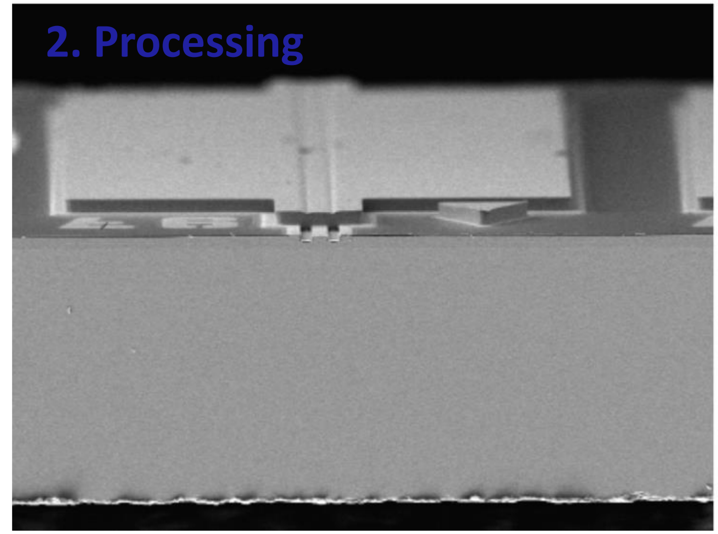


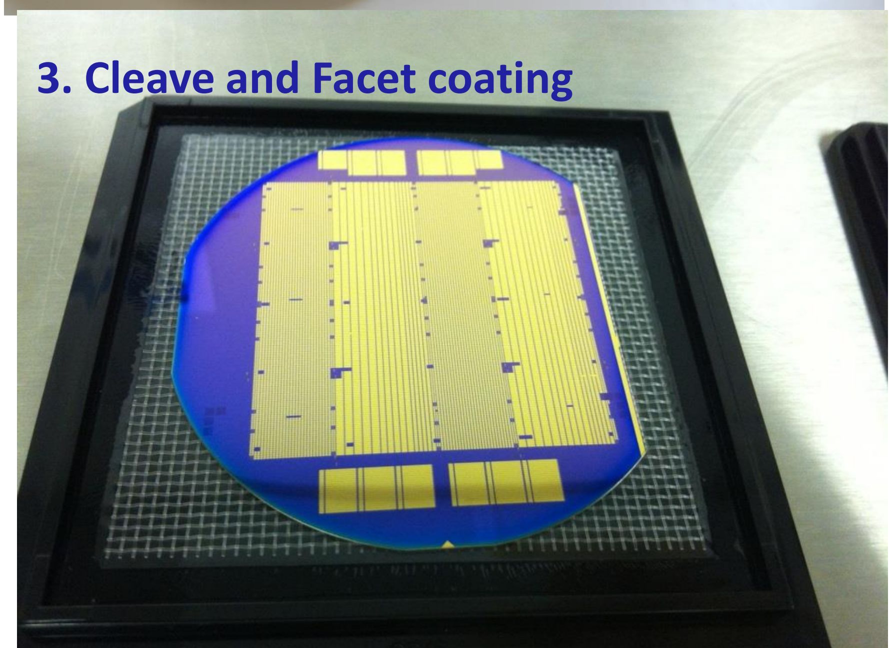




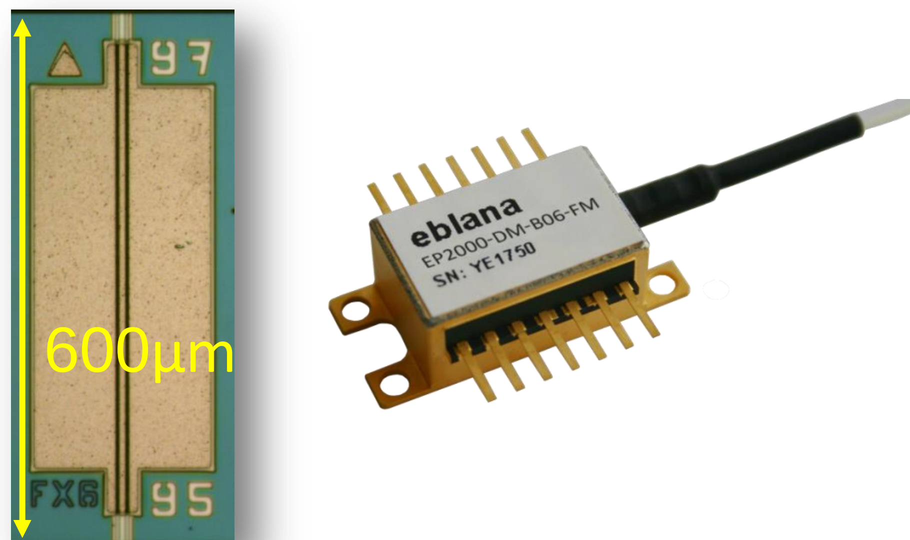
Laser Manufacture



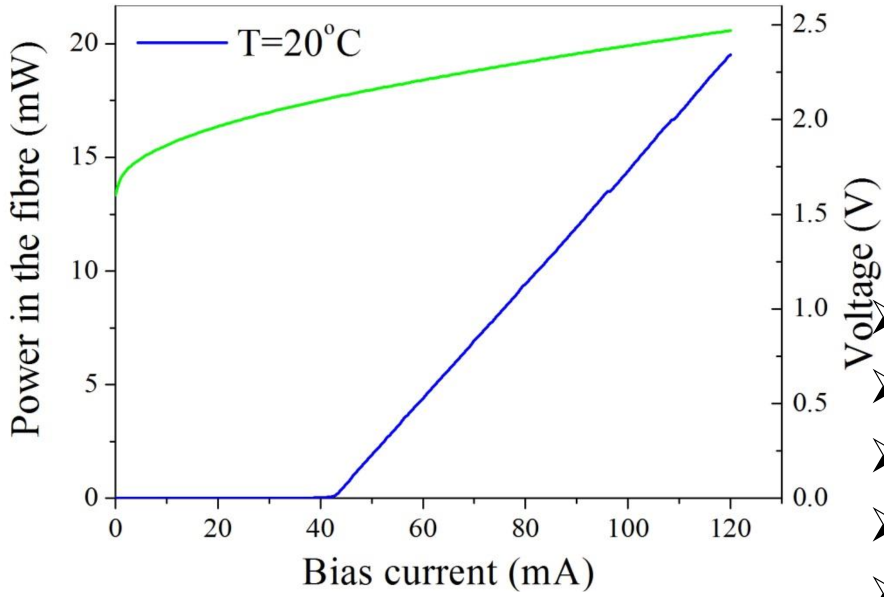


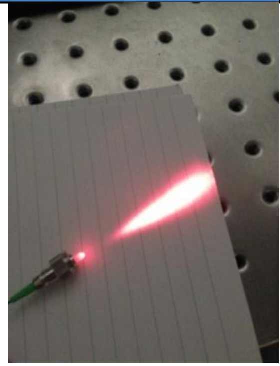


4. Test and Packaging

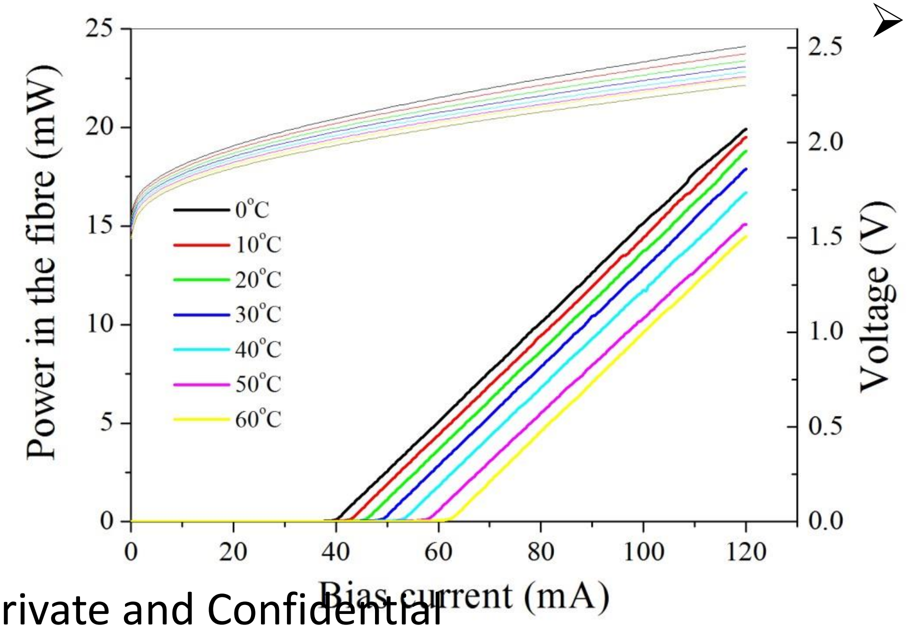


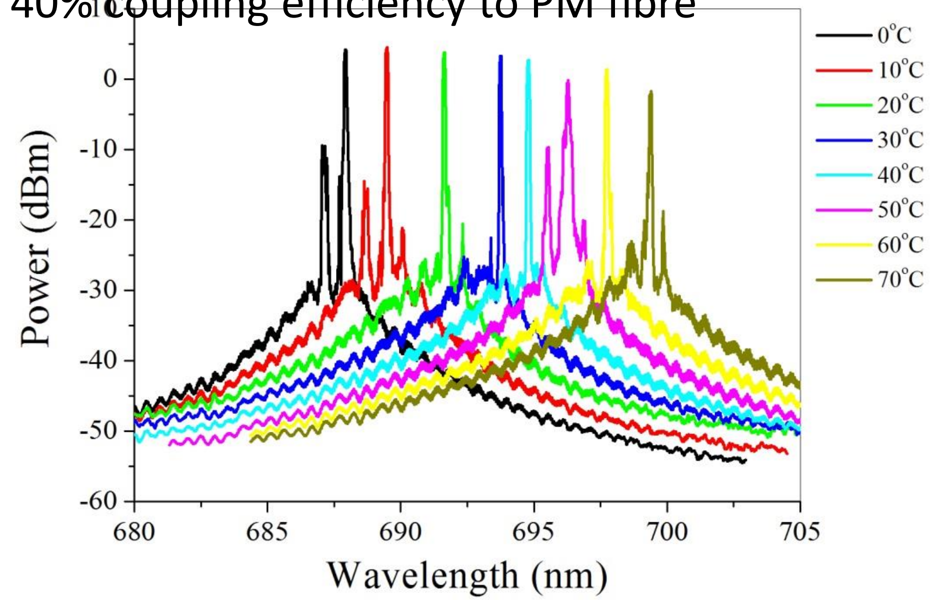
FP Laser Characteristics



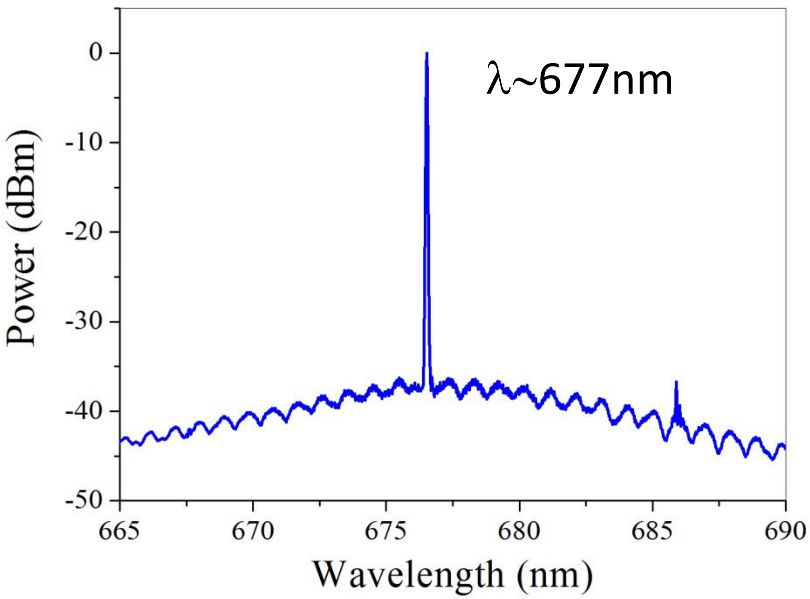


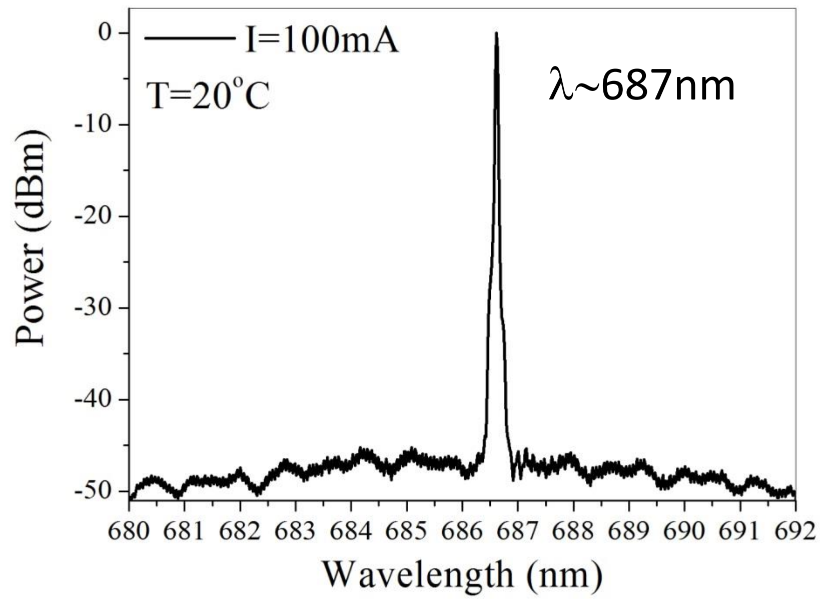
- LD 600um Rf=20% Rb=95%
- Butterfly module contains TEC, thermistor.
- No micro-isolators!!
- Threshold current ~40mA
- SE ~0.25 W/A
- 40% coupling efficiency to PM fibre

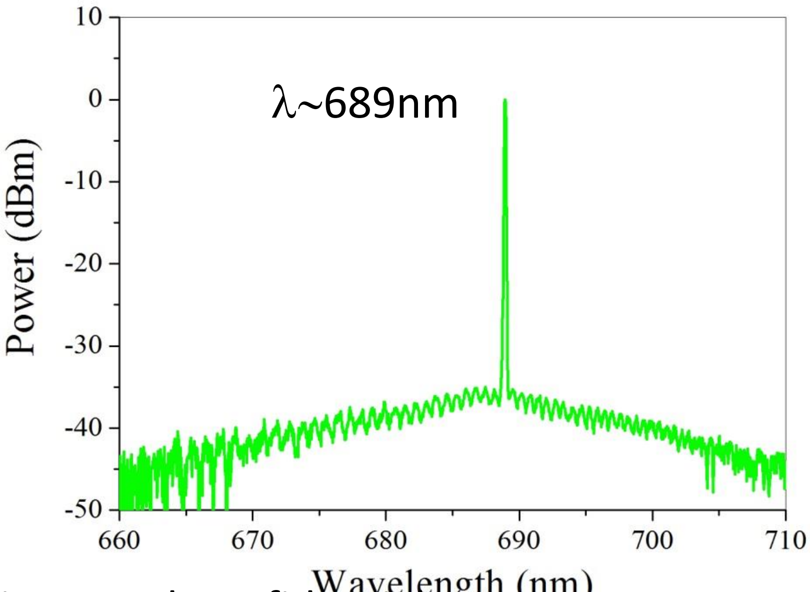


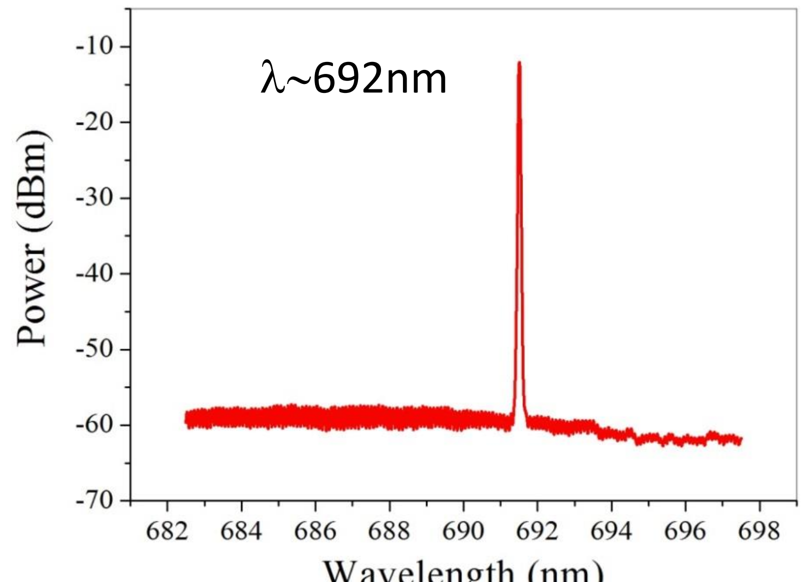


DM Laser Characteristics

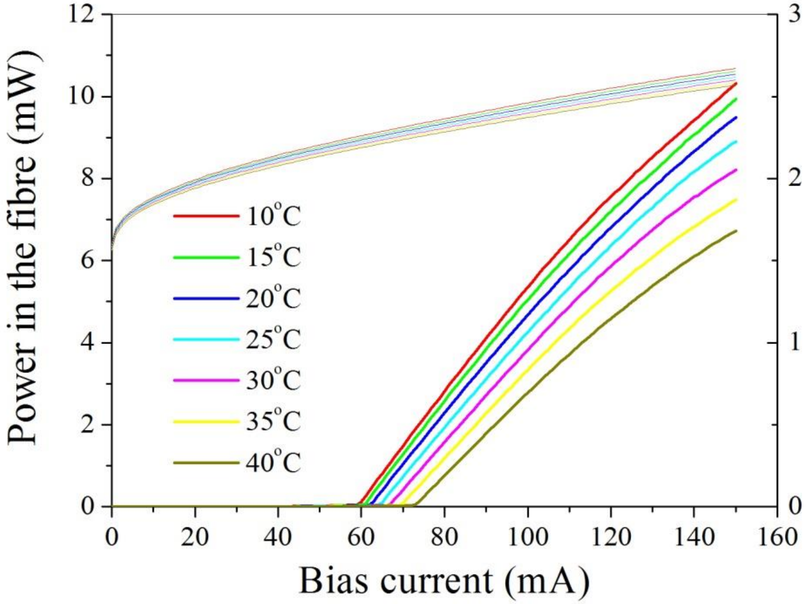


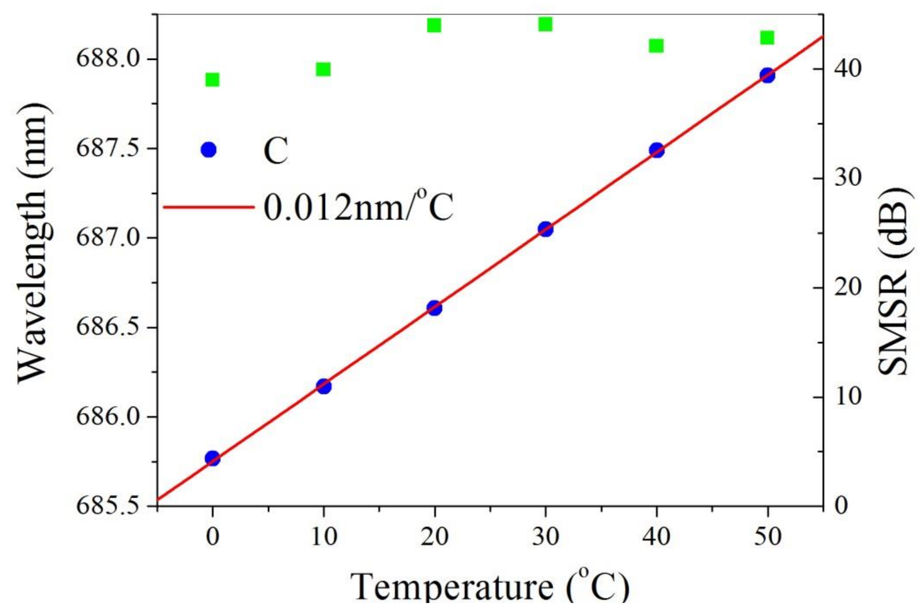


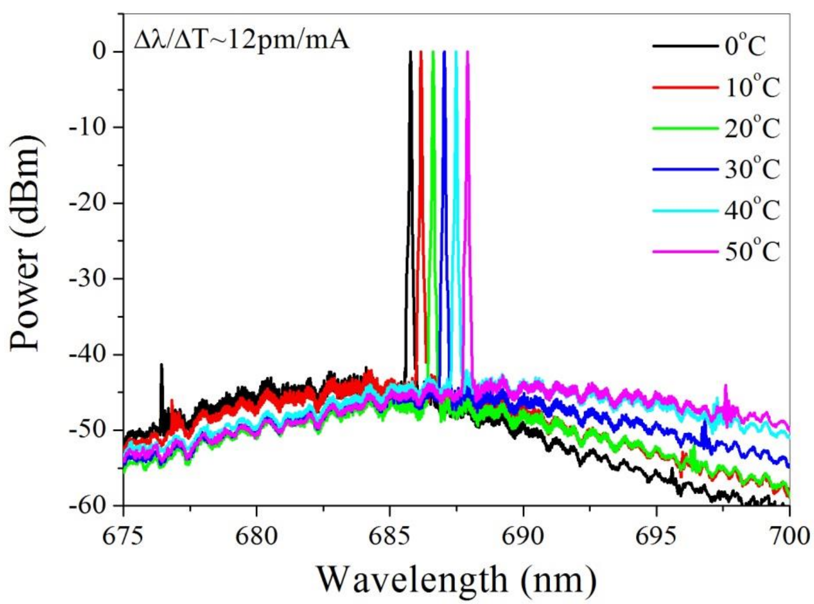


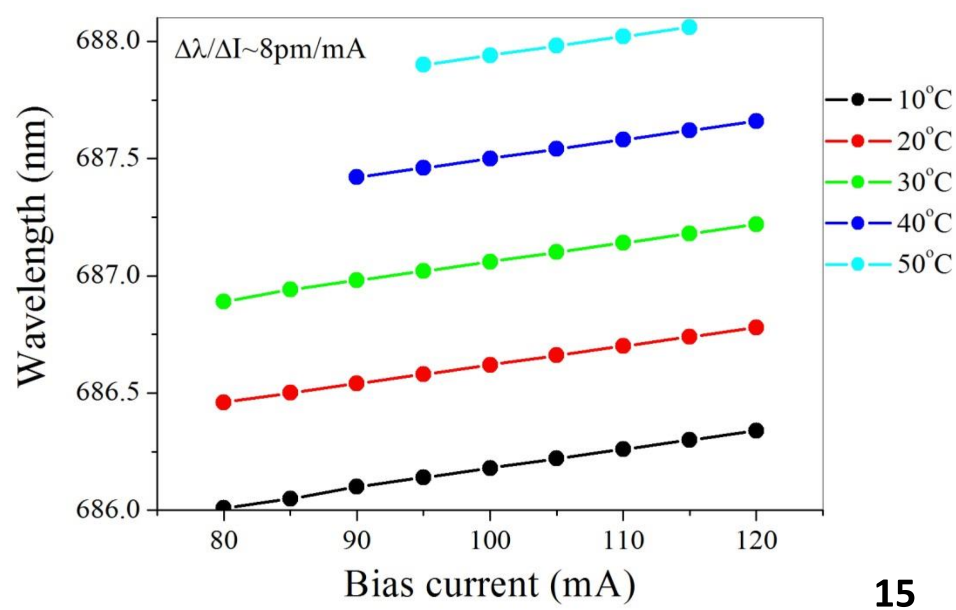


DM Laser Characteristics





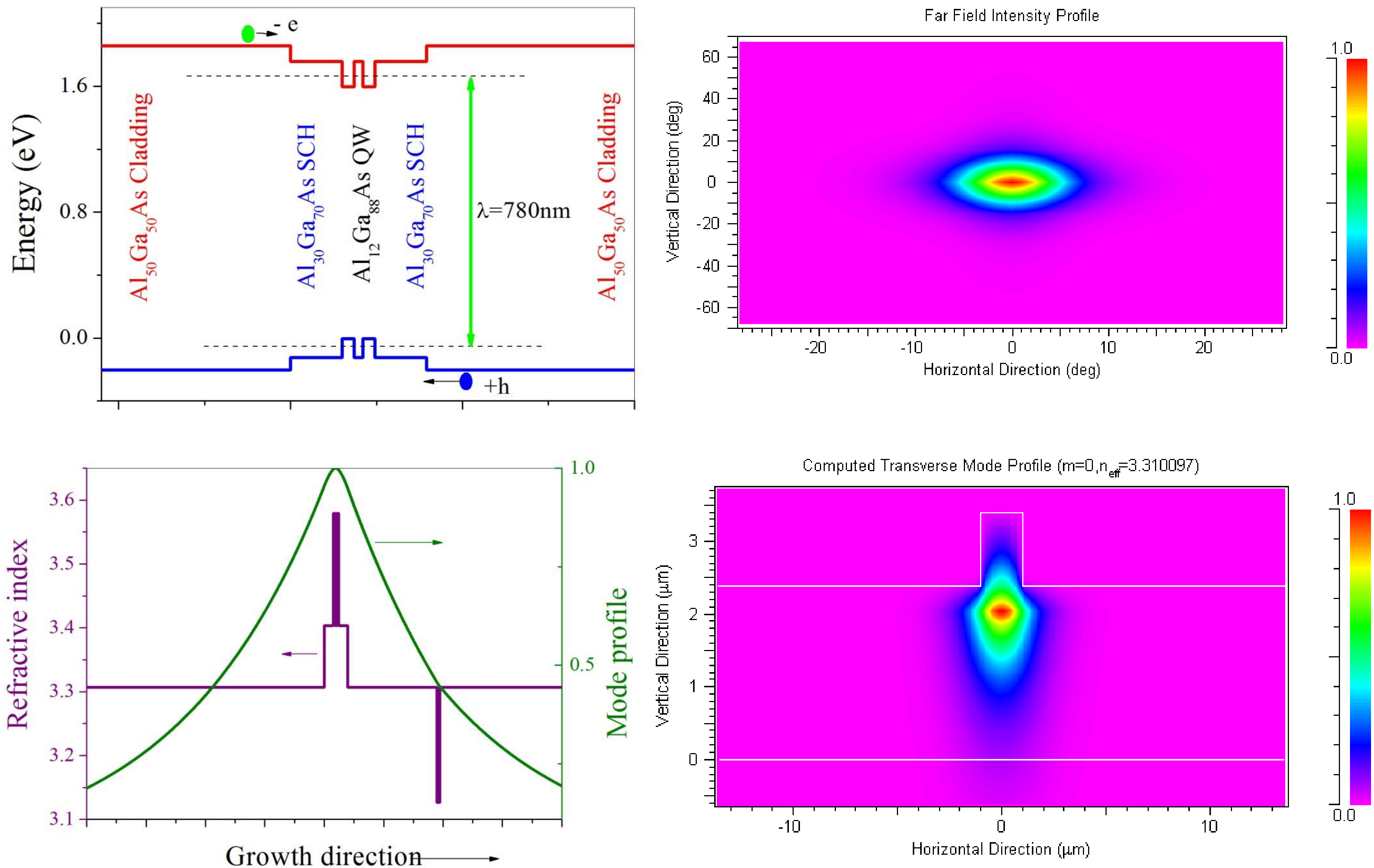




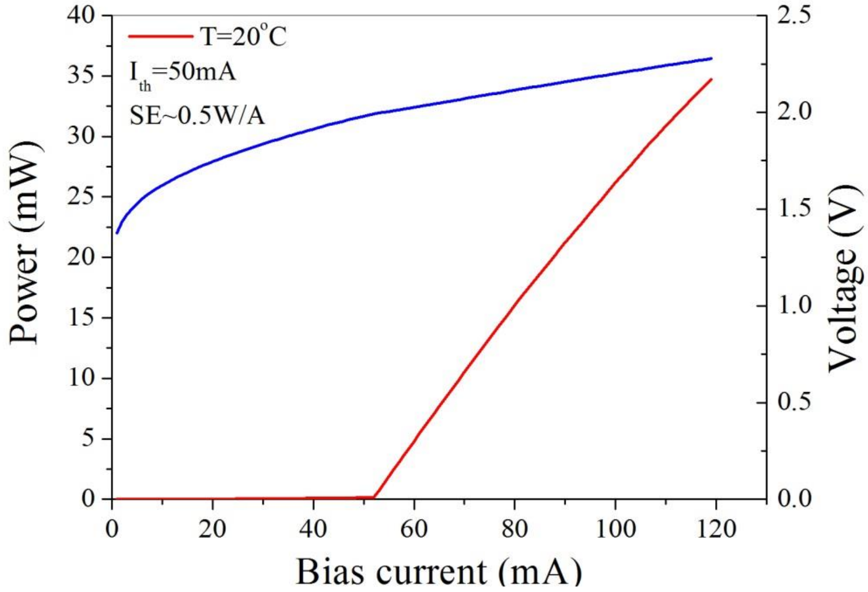
Discrete Mode Laser Diode at 780nm

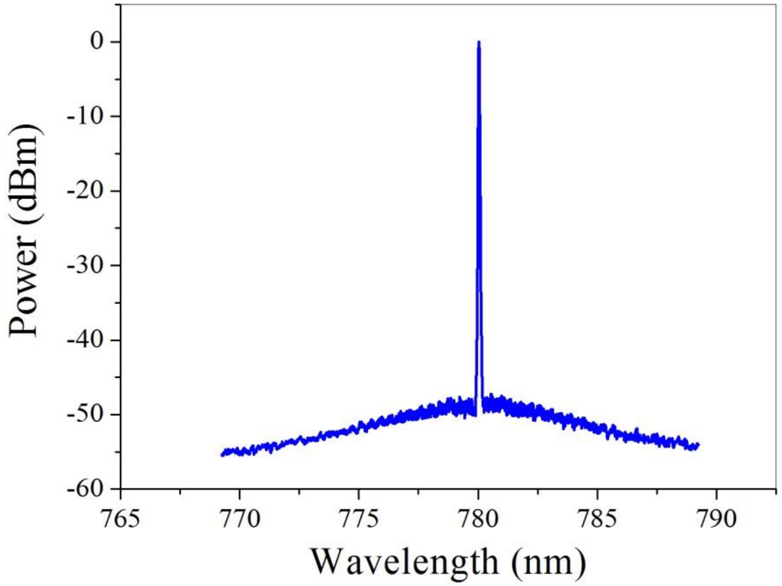
ESA contract 22472/09/CO

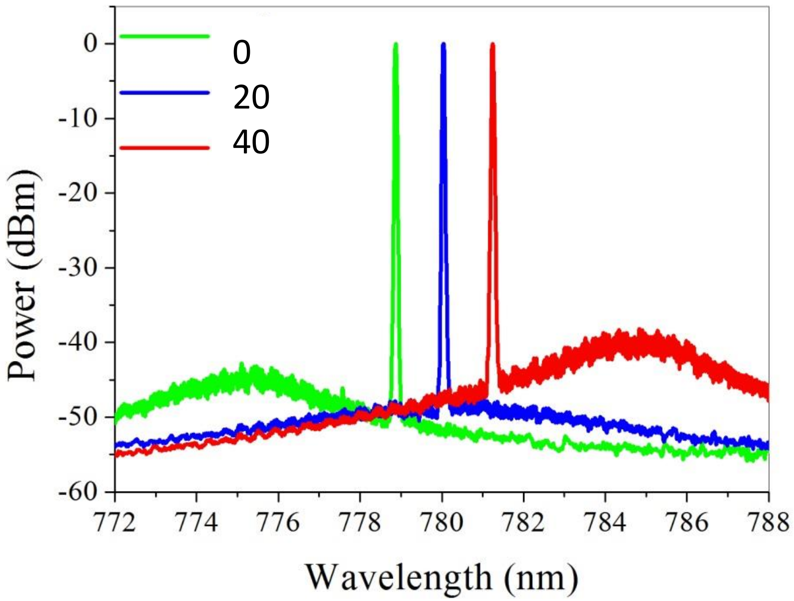
Laser emission at λ=780nm AlGaAs material



780nm DM Laser Characteristics







Design for Narrow linewidth operation

Laser diode Intrinsic linewidth is governed by the Modified Schawlow-Townes-Henry expression :

$$h_0 \sim \frac{\Delta \nu_{res}^2}{\lambda P_{out}}(1+\alpha_H^2)$$

$$\Delta \nu_{res} = \frac{v_g}{2\pi}\left(\alpha_i + \frac{1}{2L}\ln(\frac{1}{R_1 R_2})\right)$$

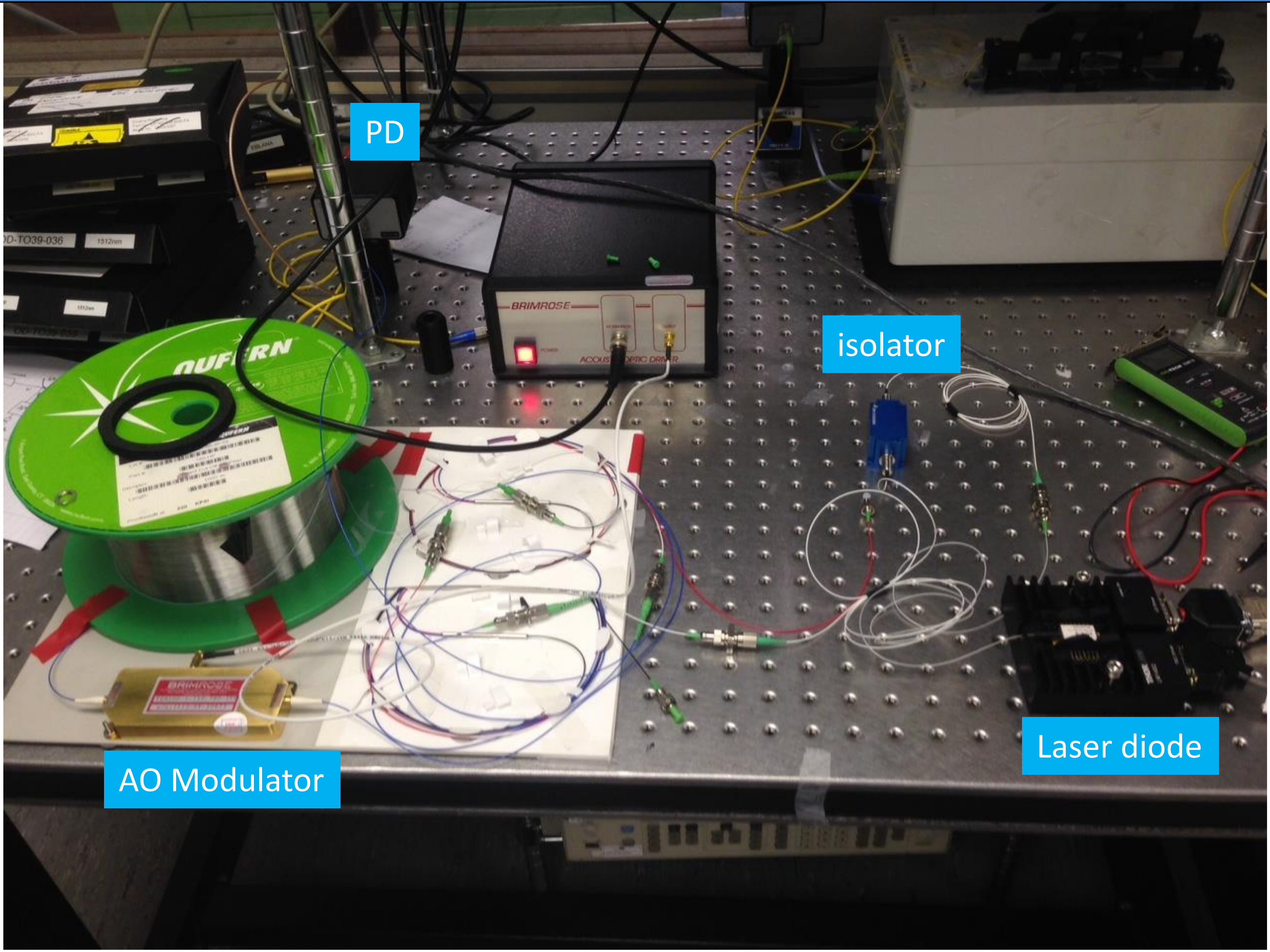
resonator linewidth

Design rules for low linewidth devices :

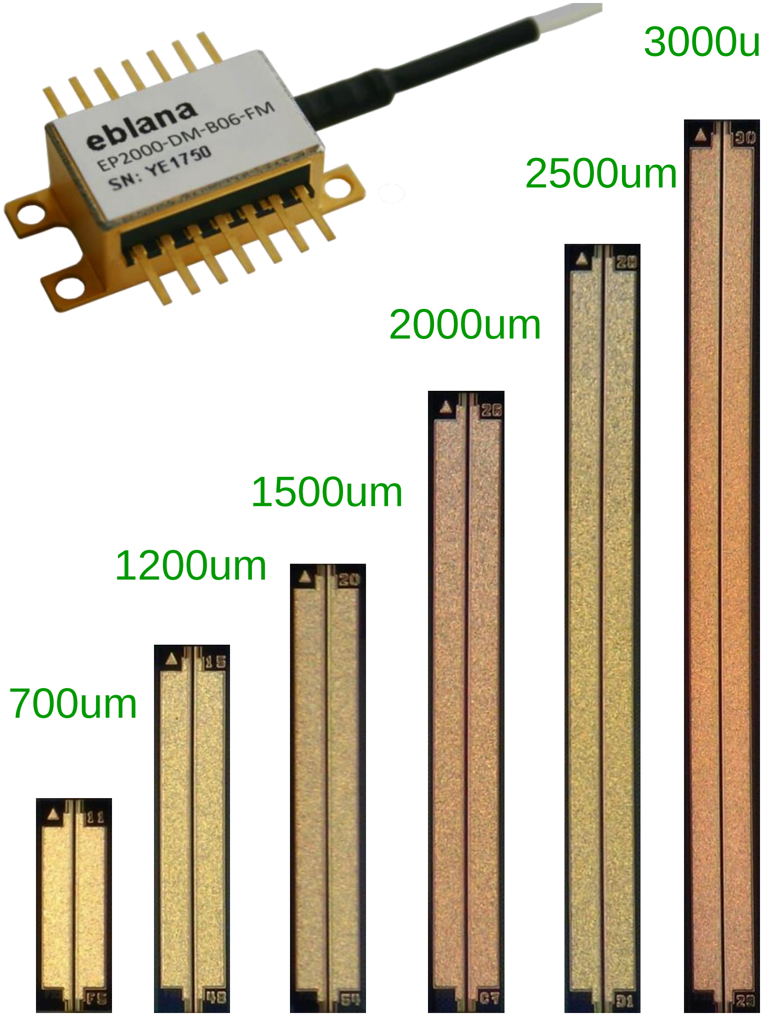
- Decreasing the α-factor → Achieved Strained MQW
- Increasing the power in the cavity P
- Reducing internal losses α_i
- Increasing the laser cavity length

} Laser Cavity Engineering

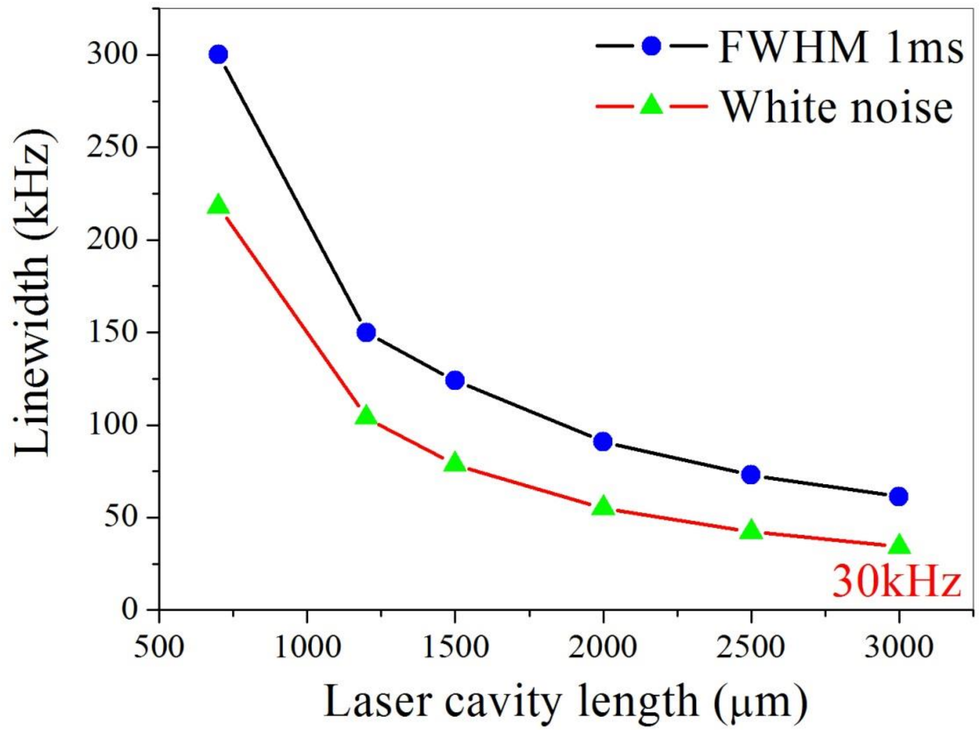
Delayed Self-Heterodyne Method.



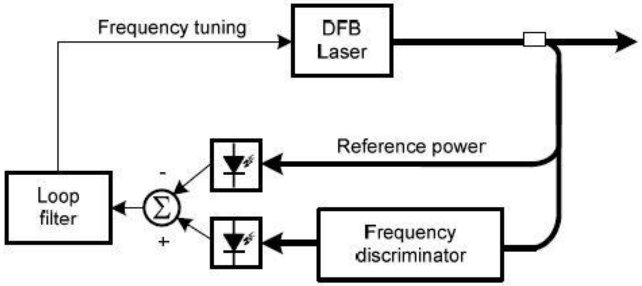
Linewidth v Laser Cavity Length

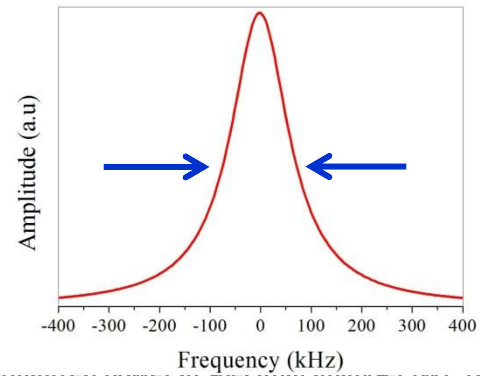


λ=1550nm



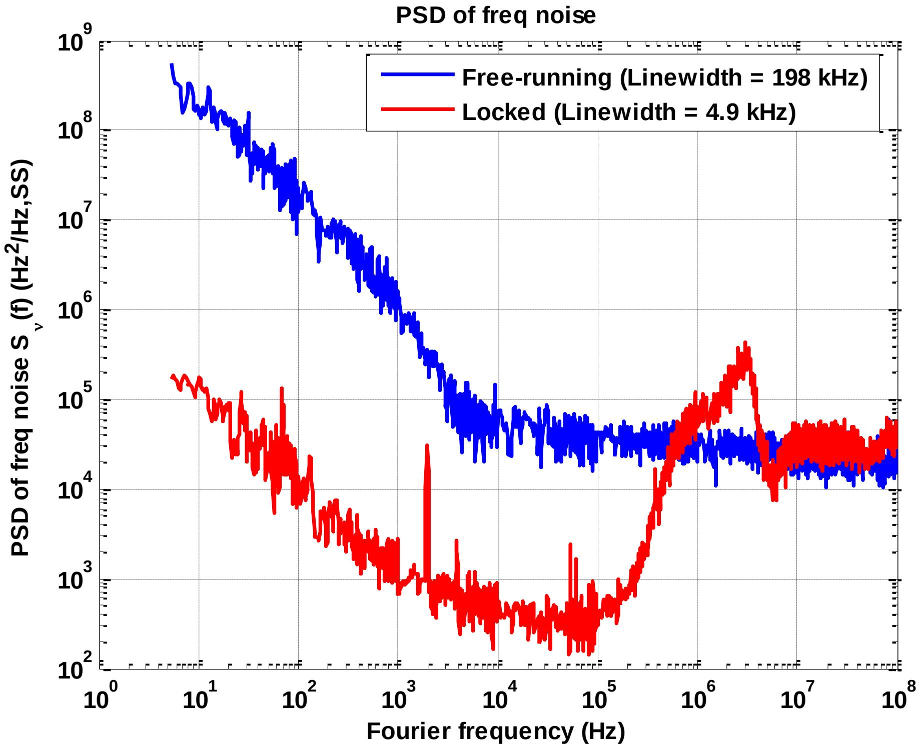
Ultra low linewidth performance

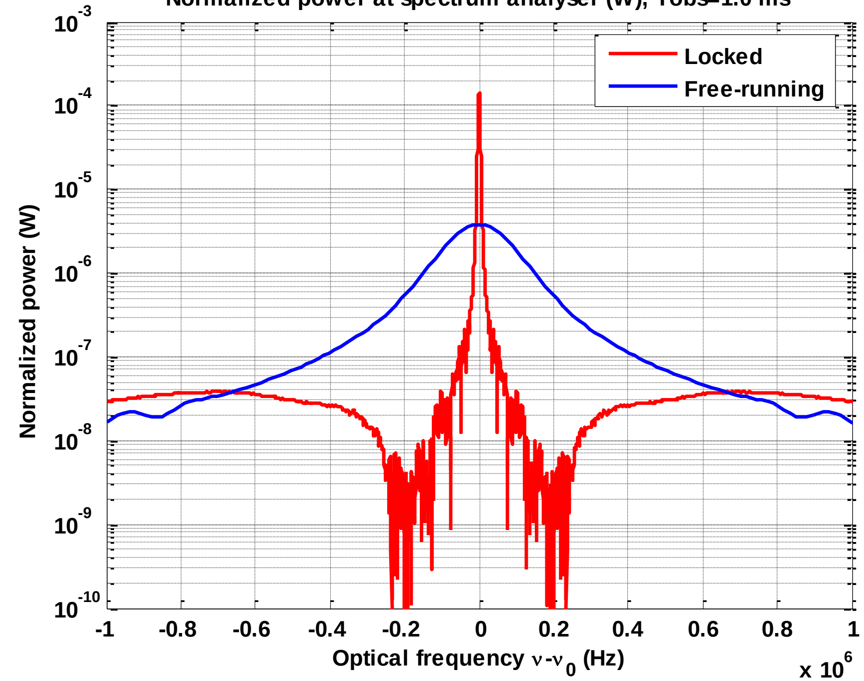




10MHz FWHM

Measured Power Spectral Density of Frequency Noise





Using external feedback orders of magnitude linewidth reduction achieved → 5 kHz !!!

Summary

- Overview of DM laser diode technology
- DM lasers operating in the 689nm region
- DM lasers operating in the 780nm region
- Narrow linewidth lasers ~5kHz demonstrated

Thank you!

E!8598 HICOLA