Diode-pumped Vertical-External-Cavity Surface-Emitting Laser (VECSEL) for atomic inertial sensors

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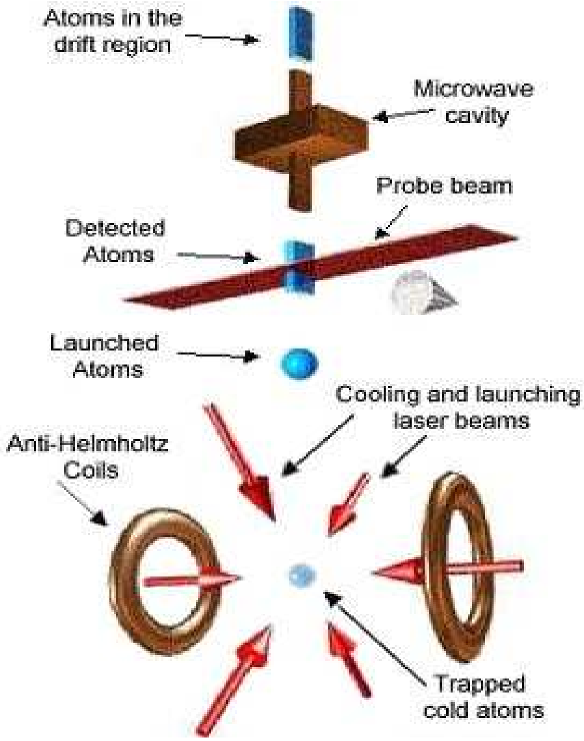
Outline

- Laser diodes in inertial atomic sensors
- Principle of VECSEL's
- Our technological choices
- Experimental setup and results
- Prospects

Laser diodes in inertial sensors

- Inertial sensors = Atomic clocks, gyrometers …



Scheme of an atomic clock (Cs λ=852 nm)

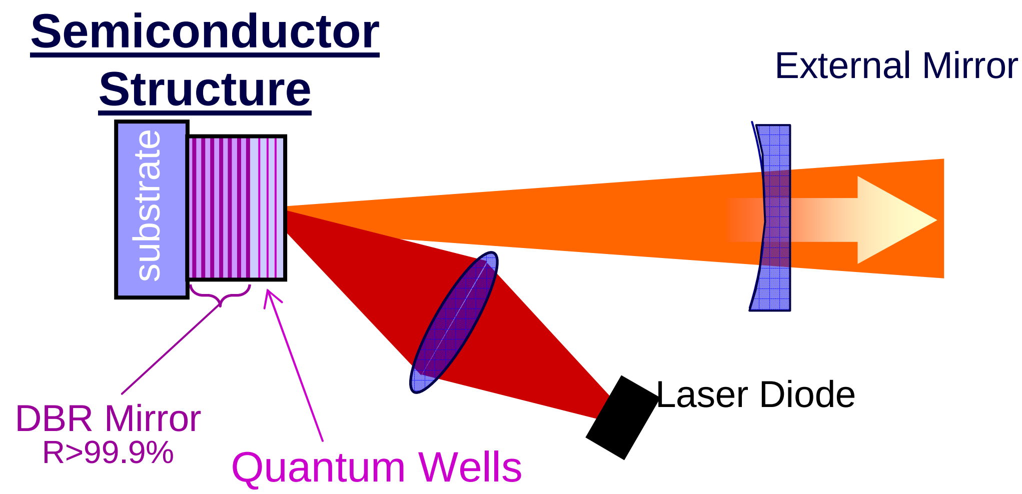
- Atom cooling : P > 200 mW
- **Launch**
- Atom preparation (Pumping)
- **Microwave interrogation**
- Detection : $\Delta\nu$ < 500 kHz

High power and narrow linewidth sources ?
To achieve more compact and simple optical benches

Diode-Pumped VECSEL

VECSEL = Vertical-External-Cavity Surface-Emitting Laser

Kuznetsov : >0.5-W Diode-Pumped VECSEL with circular TEM_{00} beam, J. Sel. Top. in Quantum Electronics, Vol.5, No 3 May 99



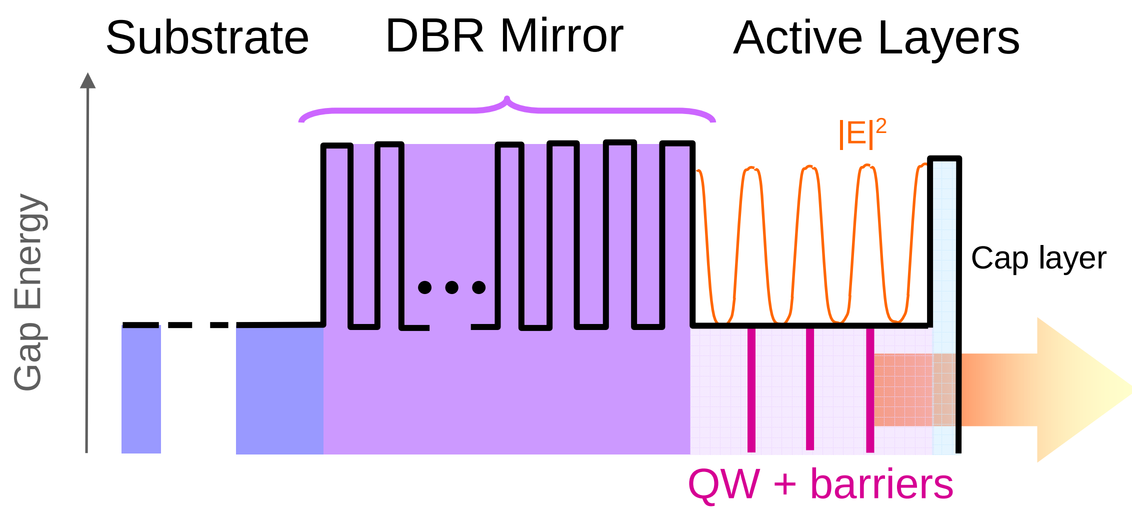
- External cavity : high power + good beam quality

  choice of the beam waist - pump radius / high damage threshold
- Design semiconductor structure : diode pumping / choice of the wavelength
- State of the art: 8-W CW VECSEL @1000nm (Lutgen et al., APL, Vol.85,N.21, May 2003)

  0.5-W CW at 850 nm (Hastie et al., IEEE PTL Vol.15,No7, July 2003)

  Single-frequency around 870 nm (Holm et al.,IEEE PTL Vol.11,No 2, Dec. 1999)

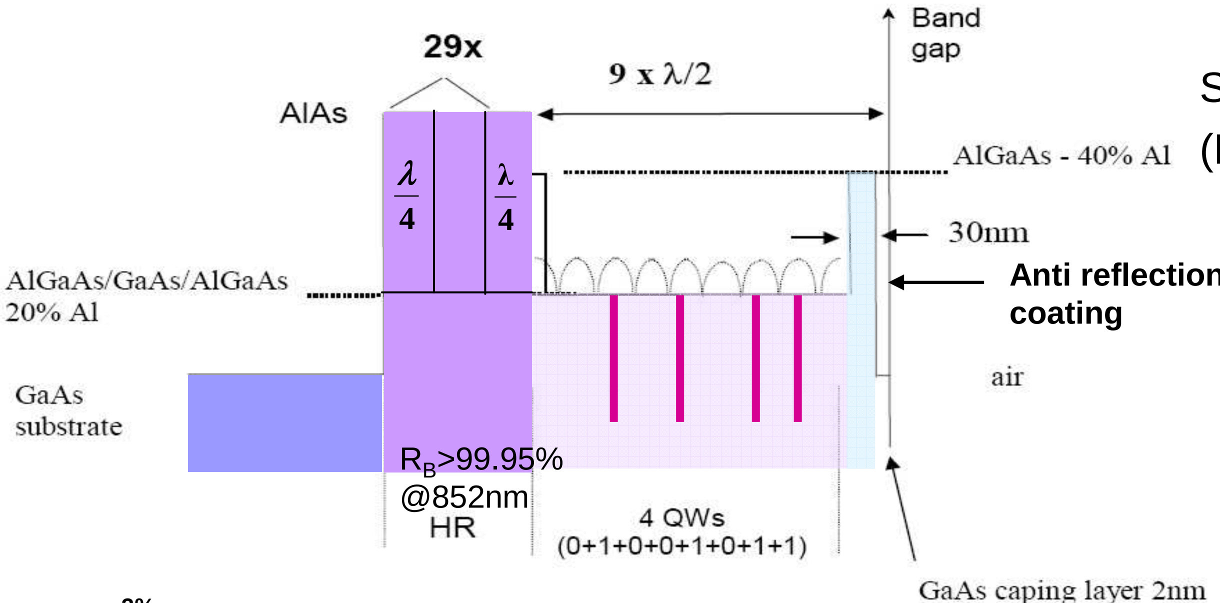
Semiconductor Structure
= Key component of the laser



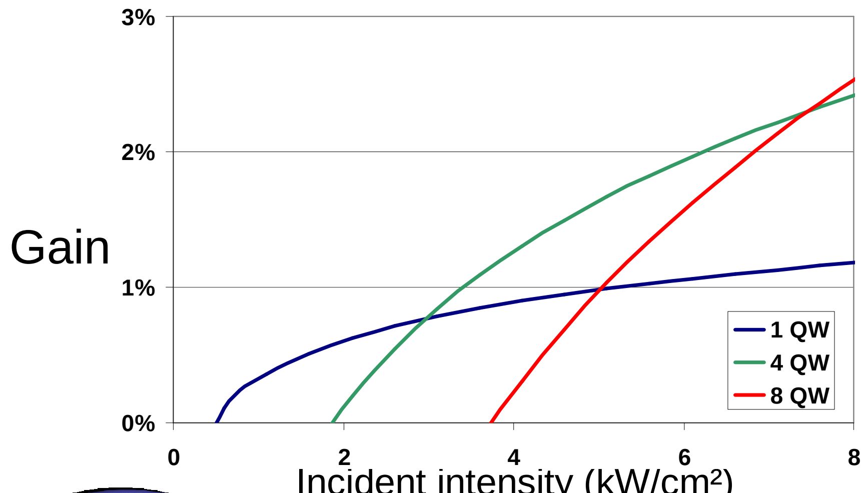
- Active layers :
  - Absorption in the barriers , gain region : QW
  - Materials : AlGaInP [550 - 700 nm] - AlGaAs [750 - 870 nm] - InGaAsP [0.9 - 1.6 µm]
  - Short absorption depth (few microns) , broad spectral absorption

    ⇒ high power multimode diode pumping
- DBR Mirror : high reflectivity
- Substrate : thermal management

Our Design at 852 nm



Structure grown by MOCVD (LPN Marcoussis)

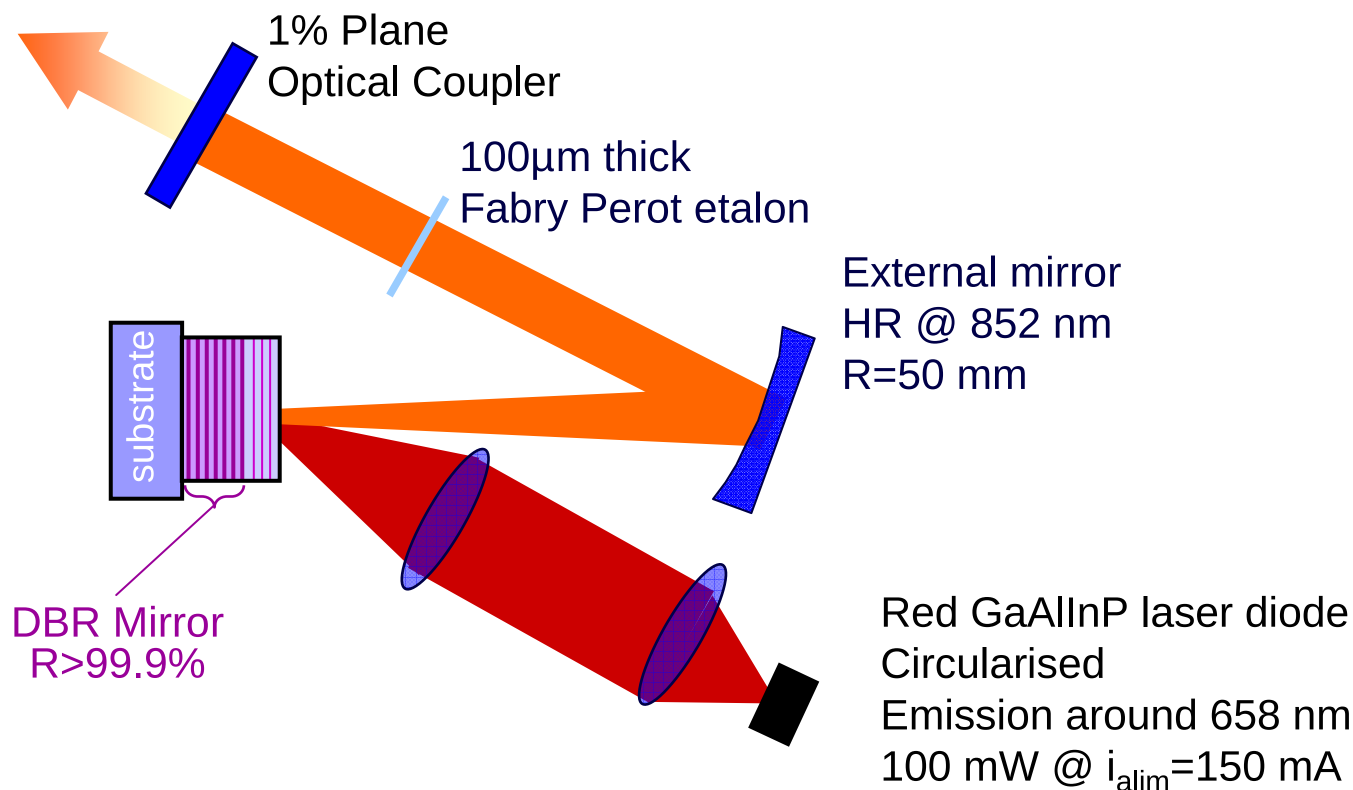


- Optimisation of the number of QW
  - low transparency
  - High gain

$$G(I_{inc}, N_{QW}) = g_0 \ln\left(\frac{I_{inc}}{I_{inc}(n_{tr})}\right) 2L_{QW} N_{QW} \Gamma$$

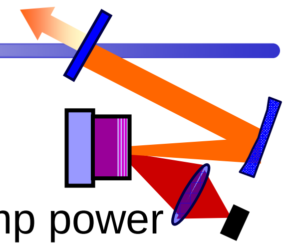
Experimental setup

- Three-mirror cavity:

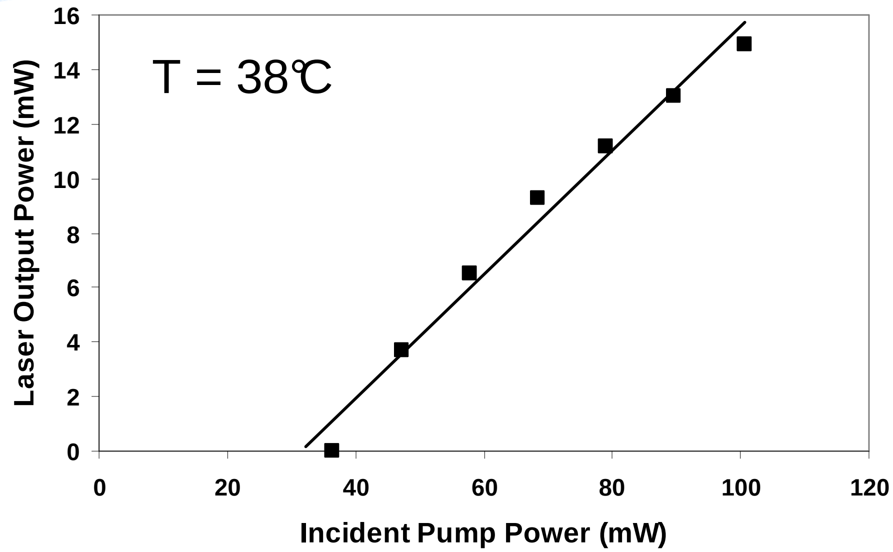


- Pump radius / beam waist radius : ~ 18 µm
- Cavity length : ~ 25 cm

Free-running operation



- Performance without any spectral selective element:



Threshold: 30mW incident pump power

~ I_{th} = 2.9 kW/cm²

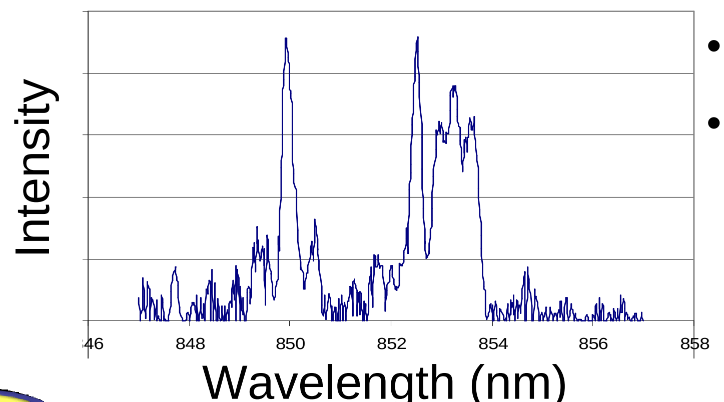
(theoretically I_{th} = 2.5 kW/cm²)

Maximum output power: P_{max} = 15mW

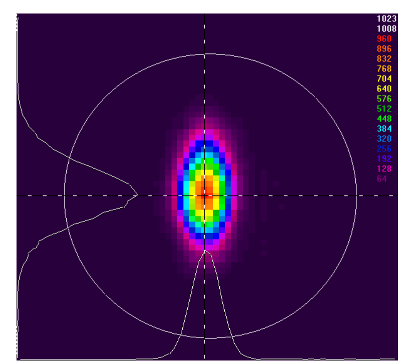
(100 mW pump power ⟷ i_{alim}= 150 mA)

External efficiency: η_{ext} = 23%

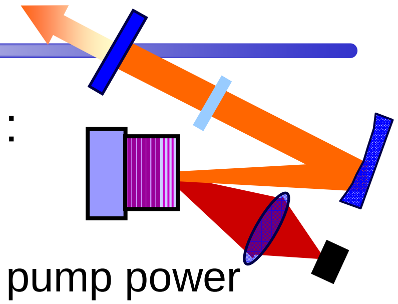
- Spectrum :



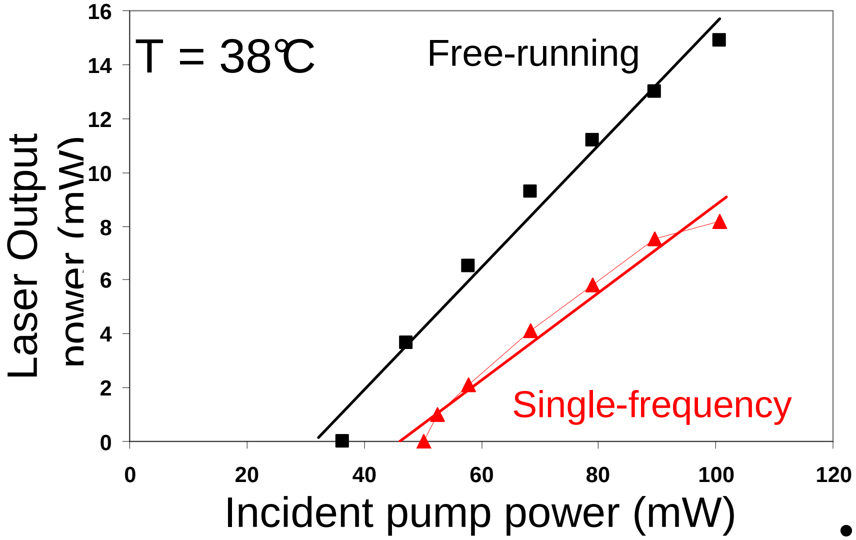
- Broad spectrum ~ 4 nm
- Good beam quality : M² < 1.2



Single-frequency emission at 852 nm



- Performance with a 100 µm-thick Fabry Perot etalon intracavity :



Threshold: 50 mW incident pump power

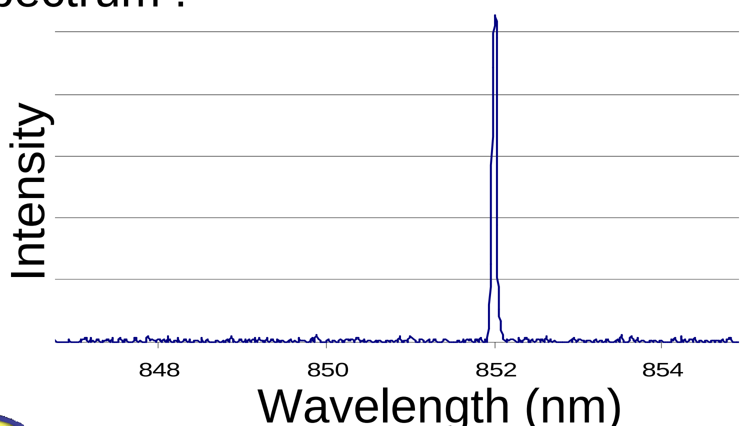
~ I_{th} = 4.9 kW/cm²

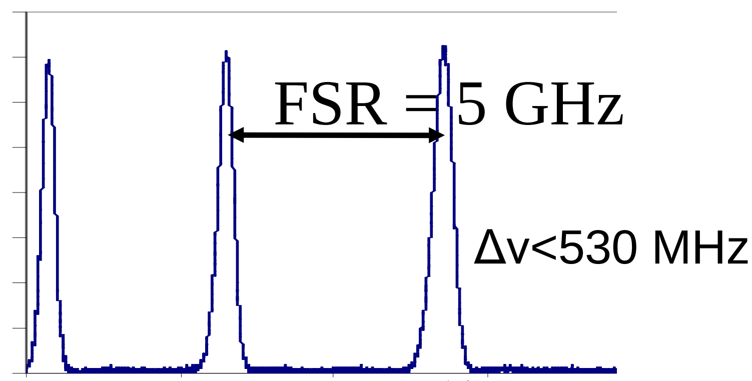
Maximum output power: P_{max} = 8.2 mW

(100 mW pump power ⟷ i_{alim}= 150 mA)

- **External efficiency** : η_{ext} = 16%

- Spectrum :





Conclusion & Prospects

- *We achieved :*
  - *15 mW CW free-running operation (100 mW / 150 mA pump current);*
  - *8 mW CW @852 nm;*
  - *single transverse mode and single frequency source.*
- **Prospects :**
  - **Development of a monolithic and compact source for evaluation at the SYRTE**
  - **Power scalability**
  - **Thermal management**
- Acknowledgement :
  - B. Cocquelin PhD funding by CNRS/CNES
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