WORKSHOP - Laser diodes in space

Requirements/Needs Expression

Development of semiconductor laser devices for Space applications at ESA

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Summary of Discussion

1. Some thoughts on the purpose and objectives of the meeting
2. ESA internal Project and Funding structure
3. ESA past/ongoing/future funded studies [technical/studies]
4. Additional ESA Diode laser technology aspects to be pursued [Measurement and verification]
5. Possible future ESA activities and required technologies

Purpose and Objectives of the meeting

- To establish a forum on semiconductor laser device research, development, test and space qualification

  Implicitly involving Industry

- To mutually discuss ongoing/future planned activities in this field

  How to find out what is going on in ESA/CNES
  Who is/are the points contact

ESA Internal Project Structure(1)

- **D-SCI** Planetary exploration
  Fundamental Physics **[Frequency metrology]**
- **D-EOP** Active Remote Sensing **[ν stable Seed lasers]**
  Earth Science
- **D-EUI-T** Telecom
- **D-EUI-N** Navigation + atomic clocks **[Laser pumped]**
- **D-HME** ISS Utilisation
  [ACES] ?
  [ELIPS 2]

ESA Internal Project Structure(2)

Fundamental Physics **[Cosmic Vision 2015]**

Fundamental Physics Explorer mission

Remote Sensing, Earth Science [Earth Explorer selection, June 06]

[CO_2, H_2O, O_2 and CH_4, N_2O, O_3] LIDAR [Possibilities]

Navigation

On board clocks for “GALILEO II” [Laser pumped]

ELIPS 2

Space Optical Clocks [Single ion, Cold atom]

What are the relevant solid state technologies?

- Low to High-power laser diode multimode emitter/ bars / stacks [Y. Durand, M. Jost]
  - CW pumping [1- 30 Watts] at 808, 9xxnm
  - QCW pumping [>/=100 Watts peak power]

  Qualification + reliability aspects
- Narrow bandwidth semiconductor devices [10's mW]
  - Fabry Perot type lasers *
  - DFB/DBR *
  - Amplifiers [100's mW]
  - DBR fiber lasers/VCSEL's
  - Fiber lasers [Mode-Locked] *

* Ongoing activities at ESA

ESA past/ongoing/future funded studies(1)

Water Vapour DIAL **(935/942nm)** $\Delta\nu_d$ **= 50 MHz (14 seconds)**

$\Delta\nu_i$ **= 1 MHz (1 msec)**

Solutions Implemented on breadboard

ECDL , DFB

[Both types achieved $\Delta\nu_i$ however DFB better suited to $\Delta\nu_d$ requirement

Future D-EOP LIDARS

Frequency stable seed lasers

CO_2	1.6 or 2.1 μm (Direct or Coherent detection)
CH_4	
O_2	0.76μm

ESA past/ongoing/future funded studies(2)

Laser pumped Rubidium gas cell clock [780nm/795nm]

Solutions Implemented @ 780nm

ECDL (100's kHz) , FP (4-6MHz)[Poster IWOC June 2005, ESTEC]

New ITT issued under GSTP4 for this wavelength

Laser pumped Caesium beam Clock

Solutions possible at 852nm / 894nm

ECDL (100's kHz), DFB (852nm available: FBH, Nanoplus, CNES)

New GSTP4 activity @ 894nm, *

New GSTP 4 activity @ 894nm [Ultra narrow bandwidth]**

* To support GALILEO/ARTES Industrial Cs clock development

** To support a more generic approach

Laser Technologies: Clocks

- *Ultra frequency-stable Laser Diodes for Navigation :*

- *As replacement of discharge lamps in current Rb space qualified (RAFS) atomic clocks. [780nm & 795nm]*
- *As key performance element for future optically pumped Cs atomic clocks;852nm and 894nm*
  - *DFB, DBR, ECDL] linewidth < 5 MHz CW power 10-50 mW*
- *As key element for other clock designs; CPT (*), double photon resonance clock where no microwave cavity is required at 778nm*

* *VCSEL use*

- *As key technology element for future Optical Atomic Clock*
  - Required Line-widths (narrower) and output powers are different to those required for optically pumped microwave atomic clocks. Wavelengths are also quite different
  - Probe laser ultra narrow; circa 1 Hz or less!!

ESA past/ongoing/future funded studies(3)

***"Optical Frequency Comb: critical elements pre-development"**

Space compatibility aspects of a fiber laser based frequency comb

NEW GSTP4 development

*To support Optical frequency synthesis and Optical clock component development

Additional ESA diode laser technology aspects to be pursued - Measurement and verification

- Narrow band diode laser measurements
  - To support the ongoing DFB/FP activities
  - To initiate new activities aimed at ultra narrow linewidths
  - Establish consistent traceable standards in Europe
  - Sources of error in linewidth determination
    - Heterodyne vs. homodyne
    - Noise sources
    - Line shape dependencies
- Diode laser measurement laboratory
- Comparison with other measurement laboratories

Possible future ESA activities and required technologies

Optical Atomic Clocks- Some Possibilities

Single Ion	
Hg+	CKL 282nm
In+	CKL 237nm
$^{171}Yb^{+}$ [Octapole]	CKL 467nm
$^{171}Yb^{+}$ [Quadrupole]	CKL 435.5nm
$^{88}Sr^{+}$	CKL 674nm
Cold atom	
Strontium (Sr)	CKL 698nm
Ytterbium (Yb)	CKL 578nm
Calcium (Ca)	CKL 657nm
Calcium (Ca)	CKL 457.5nm
Silver (Ca)	CKL 661.2nm

CKL Required Clock laser

The Technologies to be developed

Laser Technologies:

- primary science instrumentation for EO
  - Lidar, Laser altimeter

- secondary / auxiliary instrumentation:
  - Microwave atomic clocks
    - Optical pumps
  - Frequency metrology for High precision spectroscopy
    - Optical frequency combs
  - Optical atomic clocks
    - Ultra stable lasers for clock transition probe
    - Cooling, post cooling and trapping lasers
  - Atom Interferometry
    - Raman lasers
    - Cooling lasers