Technology Activities for Spaceborne DIAL Instruments

Cavity Control Simulation and Breadboarding

EADS Astrium GmbH and ILT Aachen

18.11.2005

Noordwijk

Study Objectives

Optimisation of cavity control concept for pulsed single frequency Nd:YAG oscillators, i.e.

- **Understanding of main failure mechanisms**
- **Trade of alternative design concepts**
- **Establishment of adequate design tools**

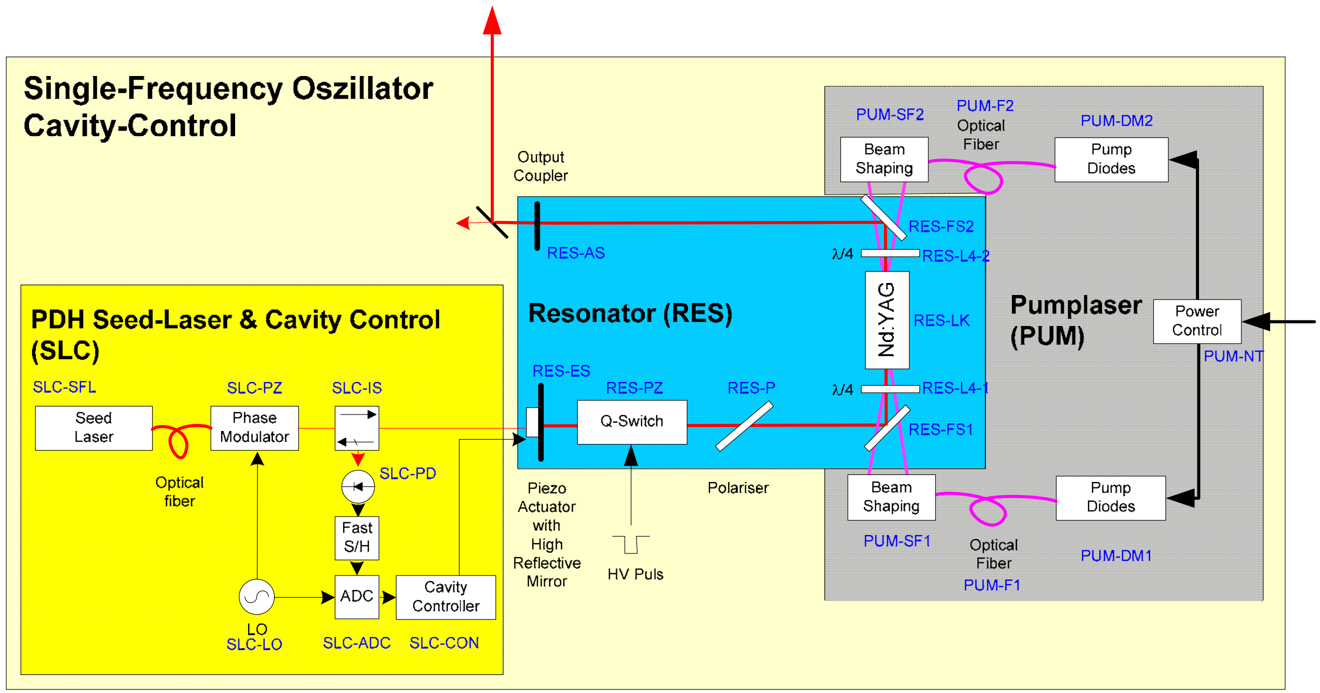
by

- **Analytical investigation of main error contributions based on single element characterisation**
- **Establishment of simulation program for sensitivity analysis wrt. error contributions in closed loop operation**
- **Establishment of flexible oscillator B/B for performance demonstration, for trading alternative design concepts and for providing further input data for simulation**
- **Comparison of H/W measurement and simulation results**
- **Derivation of optimised control concept for dedicated application**

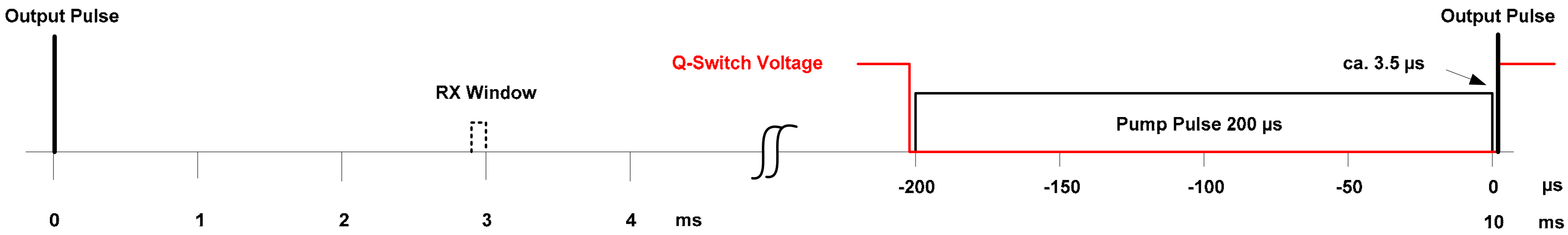
for allowing a reasonable selection of an adequate cavity control concept for different applications

Technical Concept

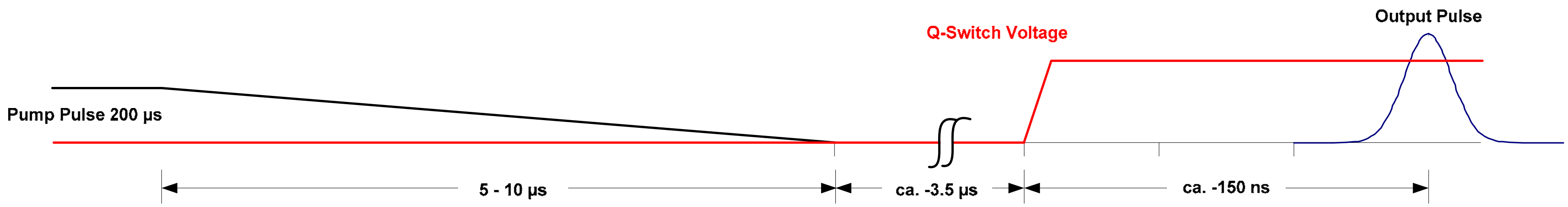
- Length ca. 1 m
- Longitudinally pumped from both sides with actively cooled diodes
- Mode diameter about 1.6 – 1.8 mm
- Pulse energy about 8 – 9 mJ
- PRF 100 Hz
- Seeding via end mirror (Alternatively via
  - Output coupler or
  - Thinfilm polariser)



Timelining



Output Pulse
RX Window
Q-Switch Voltage
Output Pulse
ca. 3.5 µs
Pump Pulse 200 µs
-200
-150
-100
-50
0
µs
0
1
2
3
4
ms
10
ms



Output Pulse
Q-Switch Voltage
Pump Pulse 200 µs
5 - 10 µs
ca. -3.5 µs
ca. -150 ns

Main Error Contributions

- Alignment errors
- Mechanical stress
- Thermal misalignment
- Microvibrations
- Laser crystal heating (length & refractive index)
- Q-switch rise time and delay
- Q-switch driver voltage stability over lifetime
- Q-switch frequency shift during switching period
- Detector dynamic range and SNR
- Piezo inertia

- Slow variations (« PRF)
- Periodically with PRF
- Fast variations (> PRF)

Alternative Control Schemes

- **Intensity based schemes**
  - Intensity maximization w. cavity as FP interferometer
  - Ramp-(Hold)-Fire Technique
  - Minimum pulse build up time

  \+ Output frequency directly detected
  \- Limited accuracy of max/min detection
  \- Mirror dithering required (ramp & fire)

- **Backreflection based schemes**
  (interference of cavity signal with reference laser)
  - Polarization based methods (Hänsch/Couillaud etc.) needs polarizer at given angle inside cavity, dispersion results in elliptical polarized light, analyzed with polarizing beamsplitter

    \- Measurement in pulse gaps
    \- Sensitive to alignment errors etc.
    \+ Medium accuracy

  - Intensity based methods

- **Pound-Drever-Hall** (symmetry of sidebands)
  - Used for high precision frequency stabilization, requires phase modulation with EOM

  \- Measurement in pulse gaps
  \+ High accuracy
  \+ Can compensate microvibrations
  \- Additional parts and modulation needed

- **Heteorodyne Detection**
  - Detection of beat signal between seed signal and output pulse

  \+ Output frequency directly detected
  \- High effort for high pulse bandwidth

Study Approach

- **Flexible breadboard design for**
  - **Overall performance assessment**
  - **Test of alternative control concepts**
  - **Measurement of dedicated parameter dependencies**

- **Optical model of cavity incl. beamwalk (microvibration), polarisation, dispersion, etc. for**
  - **Overall performance simulation**
  - **Analysis of error dependencies**

  Separate modelling of special transient effects (e.g. Q-switch)

- **H/W characterisation of special parts (e.g. Q-switch)**

(The establishment of a space compatible design has only a low priority)

Target Requirements

- **Cavity control mainly impacts frequency stability and pointing stability.**
- **Requirements differ significantly for next ESA lidar missions.**

Frequency Stability

- **DIAL** - **Absolute frequency stabilised by gas cell**
  - **Stringent for mixed garnet concept**
  - **Less critical for doubled Nd:YAG with OPO or Ti:Sa**
- **DWL** - **Stringent, depending on Mie filter bandwidth and calibration periods**
- **Backscatter Lidar** - **Less critical due to intensity measurement**

Pointing Stability

- **DIAL** - **Stringent for ensuring illumination of identical atmospheric volume with all beams**
- **DWL** - **Stringent, as mapping into Doppler frequency**
- **Backscatter Lidar** - **Less critical**

Target Requirements

- Wales and Atlid selected as reference for requirements definition
- Aladin developments used as reference for parameter values assessment

Frequency Stability	total	S/C Pointing	Thermo-mech Deform.	Amplifier	Oscillator	Seeder
Aladin (UV)	<60 MHz PtV / 1 week 4 MHz / 7 s					
Atlid (UV)	±30 MHz / month ±10 MHz / min					
H_2O DIAL	50 MHz absolute					

Pointing Stability	total	S/C Pointing	Thermo-mech Deform.	Amplifier	Oscillator	Seeder
Aladin	<100 µrad / liftime <15 MHz / 1 week <40 µrad / 7 s					
Atlid	<50 µrad / short term <100 µrad / lifetime					
H_2O DIAL	<13 µrad / 30 ms					

Status

- Study launched in September
- Critical areas and data missing for modelling identified
- Definition and organisation of special measurements in preparation
- Need of microvibration compensation under evaluation
- PDH selected as draft baseline
- Adaptation of modelling S/W started
- Draft B/B design established
- First B/B parts procured

Schedule

ID	WP	Task Name	Start	Duration
1				
2		**Cavity Control**	**Wed 01.06.05**	**175 days?**
3		**ASG Zuwendungsaantrag**	**Thu 01.09.05**	**195 days**
4		**K.O.**	**Thu 01.09.05**	**0 days**
5	A1	Literatursuche und Unters. altern. Realisierungen	Tue 06.09.05	6 wks
6	A2	Requ. Definition Cavity Control Regler	Tue 04.10.05	2 wks
7	A3	Check Raumfahrttauglichk. HW Konzept	Thu 27.10.05	2 wks
8	A4	Definition Cavity Control Simulator	Fri 25.11.05	6 wks
9	A5	Erstellung Cavity Control Simulator	Mon 23.01.06	55 days
10		Erstellung Cavity Control Simulator	Mon 23.01.06	8 wks
11		Implementierung der Testparameter	Mon 20.03.06	3 wks
12	A6	Vergleich von Simulation und Testergebnisse	Fri 09.06.06	1 wk
13				
14		**ILT Zuwendungsaantrag**	**Thu 01.09.05**	**190 days?**
15		**Simulationen und Messungen**	**Thu 01.09.05**	**81 days?**
16	X1	Simulation des Systemverhaltens	Thu 01.09.05	43 days?
17	X2	Messung von Übertragungsfunktionen	Tue 18.10.05	48 days?
18		**Aufbau eines Labordemonstrators**	**Thu 01.09.05**	**190 days**
19	Y1	Konzeptioneller Design von Oszillator und Ca	Thu 01.09.05	8 wks
20	Y2	Definition eines geeigneten HW Konzeptes f	Thu 27.10.05	2 wks
21	Y3	Check der Raumfahrttauglichkeit	Thu 10.11.05	3 wks
22	Y4	HW Erstellung für Cavity Control Testbed	Thu 01.12.05	6 wks
23	Y5	SW Erstellung für Cavity Control Testbed	Fri 20.01.06	4 wks
24	Y6	Tests mit Cavity Control Testbed	Fri 17.02.06	60 days
25	Y7	Vergleich von Simulationsergebnissen und M	Fri 12.05.06	4 wks
26			Mon 05.09.05	10 days?
27		**Progress Meeting 1**	**Mon 24.10.05**	**0 days**
28		**Progress Meeting 2**	**Tue 10.01.06**	**0 days**
29		**Test Review**	**Mon 17.04.06**	**0 days**
30		**Test Results Review**	**Thu 08.06.06**	**0 days**