



# Multifunction laser source for ground and airborne applications



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OPTRO 2010, Paris, 4st of February 2009 (1784861)

# Outline

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- q **OPERATIONAL REQUIREMENTS**
- q **FUNCTIONAL ARCHITECTURE**
- q **TECHNOLOGY DRIVERS**
- q **PERFORMANCES**
- q **CONCLUSIONS**

# Context

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- q Laser is involved in lots of military platforms and for very different applications or functions.
- q Rangefinding were soon generalized on all platforms and are still used nowadays.
- q Others, such as designation of guided munitions, were used by elites and for specific missions.
- q Clear tendency to democratization of laser function while customer asks for smart price.
- q Except for US market, the required quantities for those product are always in the range of several 10': Does not allow benefiting of large quantity effect.
- F One of the solution to overcome this problem is to offer a standard product dedicated to cover most of the requirements.

# Operational requirement

Platforms	Operational functions	Special ground soldier
	Eye-safe rangefinding (<5km)	
	Eye-safe rangefinding (>10km)	x
	Target designation	x
	Pointing for night vision device	x
	Active imaging for ID	x
	Optical sight detection (<5km)	x
	Laser Decoy (<5km)	
	Missile countermeasure (<5km)	
	Obstacle detection	
	Mine detection	
	Biological and chemical agent detection	x
	Optical damaging	
	Optical dazzling	

q The eye-safe laser rangefinding is a highly...  
 q The target laser designator provide targeting for laser guided bombs, missiles, or precision artillery munitions, such as the MBDA/Matra Baé dynamics or Paveway series of bombs, Lockheed-martin's Hellfire Sagem's AASM, krasnopol, Copperhead...  
 The laser designator places coded laser energy on...  
 q Missile counter measure such as laser jamming uses a laser to blind the infrared sensor of the man-portable surface-to-air missiles.  
 CILAS has recently tested a demonstration prototype...  
 q Obstacle detection: One of the major challenges in designing intelligent vehicles capable of autonomous...  
 q Biological and chemical agent detection by laser (LIDAR): a short laser pulse is transmitted through the atmosphere, then a portion of that radiation is...  
 q Laser dazzling consists in irradiating an enemy with light of sufficient power to disrupt its ability to aim at a given target.

# Functions analyses

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- q The most important and common functions across both airborne and ground platforms are the ability to perform eye-safe rangefinding and target designation. These core functions must be addressed.
- q Others functions such as active imaging, pointing, missile countermeasure, optical sight detection, biological and chemical detection receive medium priorities.
  - ~ Some can be considered as additional functionalities of the core functions: Active imaging, optical sight detection, laser decoy and pointing belong to that category.
  - ~ Some others require specific performances : Missile countermeasure requires laser in the MIR bands with high repetition rate (several tens of kHz) while biological and chemical detection required laser in the UV and MIR band at low repetition rate

# Functions analyses

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- q Optical damaging, optical dazzling, mine detection, obstacle detection receive the lowest priority.
  - ~ GUAV not widely used in Europe
  - ~ Optical damaging leads to specific technology
  - ~ Optical dazzling tends to be abandoned
- q Operational requirements showed strong similarities between rangefinding, designation, laser decoy and flash imaging such as wavelength, repetition rate, divergence, volume, thermal operational range.

# Technology drivers : Laser crystal

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- q The designation has to be done at 1064 nm and at specific repetition rates (such as STANAG 3733) between 8 to 22 Hz.
- q The required wavelength is set by the infrared detector and the accurate optical filter in the semi active seeker of the guided munitions.
- q Retrofit of all the guided munitions through the world is a serious obstacle for an up grade to "eye safe" band.
- q Few kind of host material lasing close to 1064 nm.

# Technology drivers : Laser crystal

Parameters for 1.1 atm%,	Nd :YAG	Nd :YVO4 p pol	Nd:GdVO4 p pol.
Lasing wavelength (nm)	1064.2	1064.3	1062.9
Absorption bandwidth (nm)	10	31	
Absorption coefficient at peak (cm <sup>-1</sup> )	7.1	31,4	74
Fluorescence lifetime (μs)	230	90	90
Effective emission cross section (cm <sup>2</sup> )	2,3 · 10 <sup>-19</sup>	11 · 10 <sup>-19</sup>	7,6 · 10 <sup>-19</sup>
Thermal Conductivity Coefficient (W/cm/K)	14	5	8 to12

q Nd : YAG good trade off between high peak power and medium repetition rate

# Technology drivers : MOPA

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q Longer is the expected designation range, higher is the output energy and lower is the output divergence. Fortunately, airborne targeting pod that require long designation capability have also bigger output aperture than portable system. On the over hand, output energy shall be adapted to each platforms. A master power oscillator and amplifier (MOPA) permits to address each energy requirements by providing better flexibility for energy sharing.

- ~ Output energy bellows 90 mJ are dedicated to portable designator.
- ~ Medium output energy between 100 mJ to 150 mJ for fighting UAV and helicopter
- ~ High output energy (150 mJ to 300 mJ) for fighting aircraft

# Technology drivers : Pumping and cooling

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- q Diode pumping has a triple advantage over flash pumping:
  - ~ Compactness : 1 kW are currently available in a stack of bars of 2 mmx10 mmx20 mm
  - ~ Electrical to optical efficiency: Close to 55 %
  - ~ Less thermal load in the amplifier medium.
- q Diode bars required TEC to stabilise emission wavelength
- q TEC usually consumes twice the thermal load to remove in the operational thermal range !!

# Technology drivers : eye-safe stage

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- q Thirty percent conversion efficiencies of Nd:YAG at 1064 nm laser radiation into eye-safe region (at 1.57  $\mu\text{m}$ ) are obtained today in 20 mm OPO with KTiOPO<sub>4</sub> (KTP) crystals even with highly multimode pump lasers.
- q High beam quality OPO conversion (bellow 20 mmxmrad) has been demonstrated in a reasonable size cavity (60 to 80 mm).
- q The choice of the OPO crystal is a critical issue as it determines the performances of the conversion process

# Technology drivers : eye-safe stage

<b>Parameters given for pumping at 1064nm in non critical phase matching conditions (NCPM)</b>	<b>KTP</b>	<b>KTA</b>	<b>RTP</b>	<b>RTA</b>
$\lambda_{\text{signal}}$ (nm)	1572	1534	1616	1610
$\lambda_{\text{idler}}$ (nm)	3292	3476	3115	3137
$d_{\text{eff}}$ (pm/V)	3,6	3,2	2,6	3,4
Damage Threshold (MW/cm <sup>2</sup> )	600	600	600	600
Atmospherical transmission (%/km)	89%	88%	90%	90%
Cost/quality				

# Technology drivers : Photodiodes

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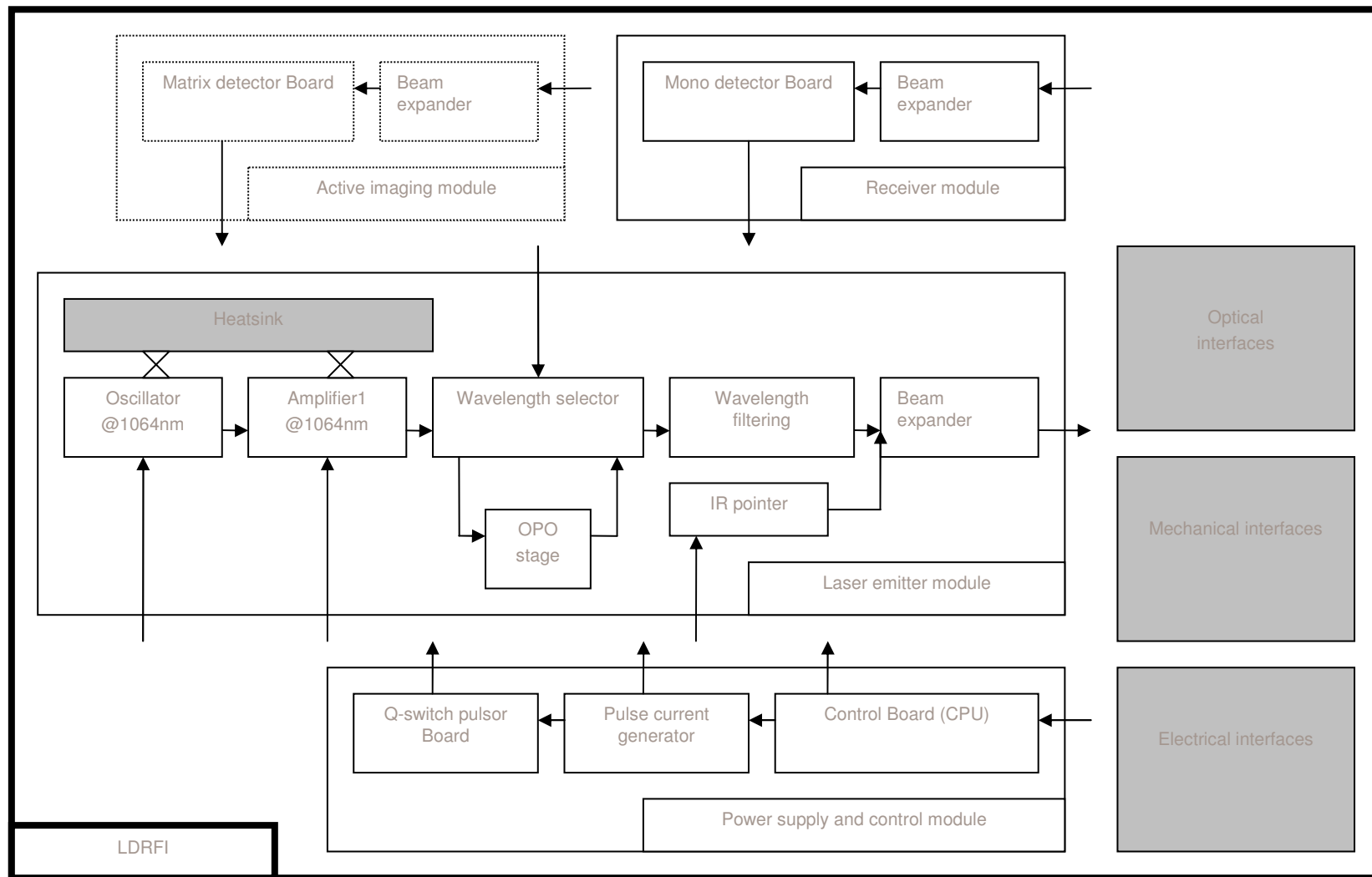
- q The top priority of this function is to provide high sensitivity particularly at 1,5  $\mu\text{m}$  where the energy of the laser is the lower one.
- q Can be optically remote upon request.
- q Photodiodes PIN InGaAs, APD Ge, APD InGaAs are available for many years with high level of performances and reliability.
- q Diameter of this component varies from 50  $\mu\text{m}$  to 300  $\mu\text{m}$ . Avalanche photodiodes (APD) gives better performances than PIN ones. The sensitivity is increased by a factor 10 or more even if APD requires a bias voltage close to 100 V. NEP between 5 nW to 100 nW were demonstrated depending of the chosen technology.

# Technology drivers : Flash laser sensor

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- q Recent developments on gated Focal Plane Array (FPA) detector technology are very promising for 2D or 3D active imaging.
- q HgCdTe (Mercury Cadmium Telluride / MCT) is a suitable material because offering dual mode capability: Active imaging at 1,5  $\mu\text{m}$  (SWIR band) and passive imaging in the MWIR band. For low flux application, the sensibility can be improved using MCT Avalanche Photodiodes Detector (APD).
- q It has been demonstrated that an avalanche gain higher than 500 could be obtained on such detectors biased with 10 Volts without increasing the noise factor  $F$  (close to 1) up to this bias voltage. Moreover the spectral and spatial response of detector are unchanged in this operating regime.

# Final architecture for LDRFI



# Estimated main characteristics

Main modules	Critical parameters	Volume (mm <sup>3</sup> )	Pcons (W)
<b>Laser emitter@1064 nm</b>	>150 mJ, <4 mm.mrad, PRF20 Hz	210x85x45	110
<b>OPO stage</b>	8 mJ, <8 mm.mrad or 35 mJ, PRF20 Hz,	25x25X160	0
<b>Wavelength selector</b>	Switching time <500 ms	55x80x140	4
<b>IR pointer</b>	1W CW, 0,8 μm	55x15x20	3
<b>Receiver module</b>	NEP 10 nW	30x30x10	4
<b>Pulse current generator</b>	150 A for η=70 %	50x50x90	33
<b>Control board</b>	RS422 remote control	100x100x10	6
<b>Q-switch pulsor</b>	2800 V, 20 ns	80x30x10	2,5

# Conclusions

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- q Multiple ground and airborne vehicles could share common and multifunctional laser modules. The host system constraints and requirements have similarities making a laser modular concept interesting
- q CILAS has developed the key technologies for providing efficient and compact multifunction laser platforms for designation, rangefinding and illumination (LDRFI)
- q Using novel athermal scheme, thermoelectric cooler are avoided leading to a compact device, ready for firing immediately after power on. No warm up time is required. This laser is particularly adapted for application where volume and weight are highly challenging (ground target designation, designator for UAV or helicopter...)