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Sub-ns Microchip Lasers Technology: Overview and Progress in Health Science and Industrial Applications

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Agenda

1. Company overview
2. Laser technology
3. Added value for the process
4. Conclusion and perspectives

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1 – Company overview

Near Grenoble, hotbed of French technology

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Corporate background

- **Founded November 1998 *(Spin-off Schneider Electric/GeeO)***
- **Privately held**
- **HQ in Meylan near Grenoble**
- **Transformed business model from telecom to commercial lasers**
  - > Pioneered integrated optical EDWA™
  - > Acquired MIT-based picolaser line in 2005 from JDSU
- **Successfully integrated acquisition**
  - ➢ 6000 picolasers shipped
- **40 people**
- **Cleanroom production facility**
- **Worldwide presence, US-sales office,15 distributors**

Secured Intellectual Property

Teem Photonics owns or controls the intellectual property relevant to all its products:

- **Exclusive IP rights on Passively Q-Switched picosecond microlaser, patent number US 5394413**
  - > pulse duration are under 1 ns
  - > or
  - > peak powers are in excess of 10 kW
  - > or
  - > ratio of peak power to pump DC power are above 10 000.
- **License agreement on high power fiber technology with IMRA**

Volume capable and flexible manufacturing

- **High End production floor**
  - Class 10000 clean rooms and class 100 workstations
  - Production of > 100 lasers /month
  - Low fixed manufacturing costs
  - Proven high production yields

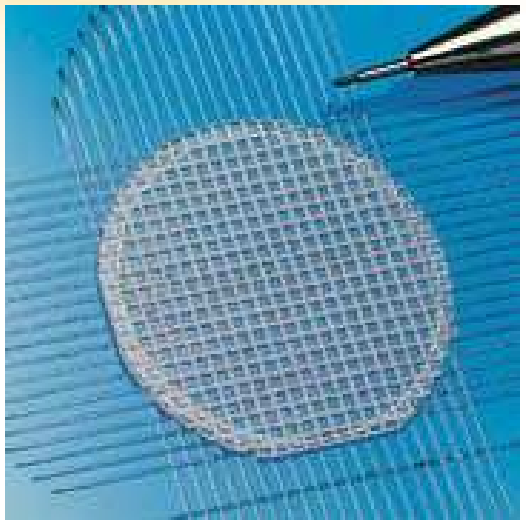
- **Strong in-house R+D team (20% of all employees)**
  - Laser design
  - Mechanical design
  - Electronics design
  - Software design

2 – Laser technology

The simplest of the Ultrafast lasers

Based on a unique technology combination:

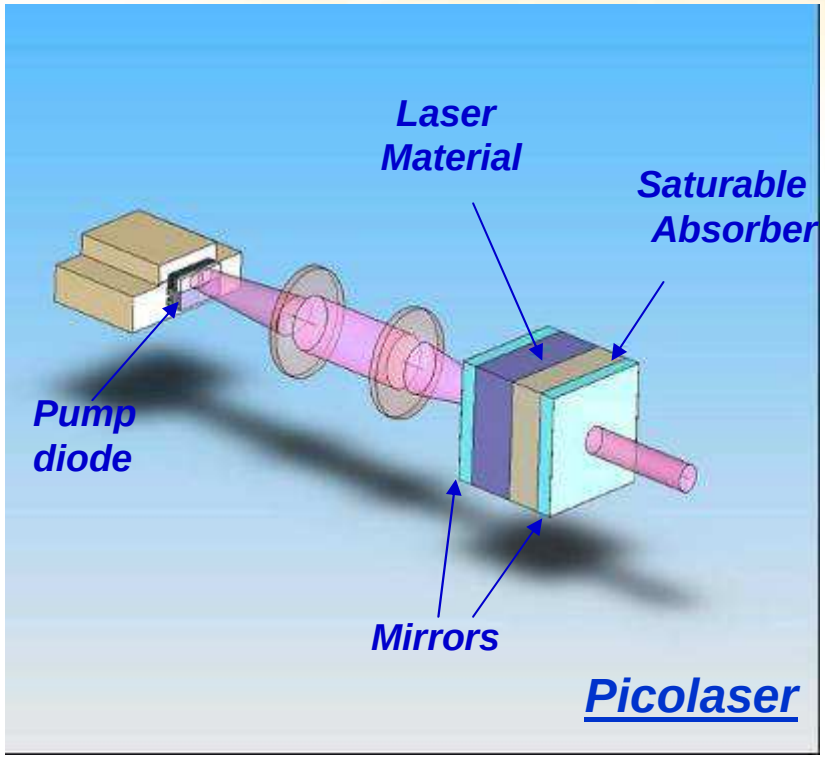
- Microchip technology
  - > Cost-effective
  - > Reliable
  - > Compact and rugged



- Passive Q-switching
  - > Remarkable pulse characteristics
  - > Naturally good beam quality

« Picolasers » = passive Q-switched microchip lasers

Picolaser principle of operation

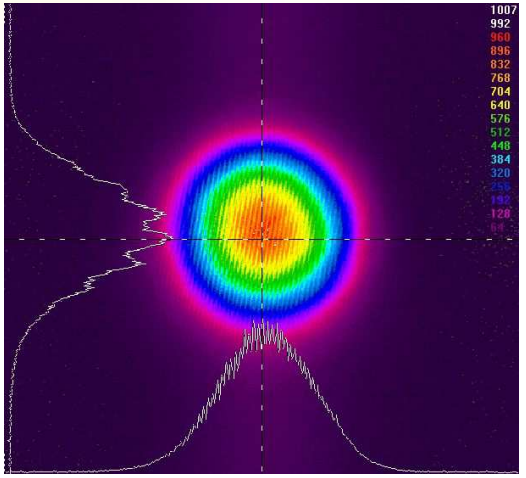


Picolasers “naturally” turns the continuous power of a semiconductor laser diode into a stream of picosecond pulses, without any external electronic devices.

- 2 main Picolaser product lines (non amplified) :
  - > **Microchip** : high repetion rate, lower energy
  - > **Powerchip** : high peak power, on-demand pulse emission

Picolasers performances overview

- At 1064nm, from the oscillator output :
  - Pulse duration : down to **300ps**
  - Peak power : up to **300kW**
  - Pulse energy : up to 100µJ
  - Repetition rate : up to **140kHz**
  - Output power : up to 400mW
  - Beam quality : TEM00, **M²=1.05 typ**.



- Reliability : Over **45,000 hours of operation** @ 1064nm
  MTTF ~ 17,000,000 hours
- Some drawbacks still…
  - Limited output power due to small cavity volume
  - Limited process orientated controls

Overcoming output power limitation

- Development of fiber-based MOPA architecture to reach higher power levels while valorizing Picolasers pulse characteristics and industrial grade reliability.

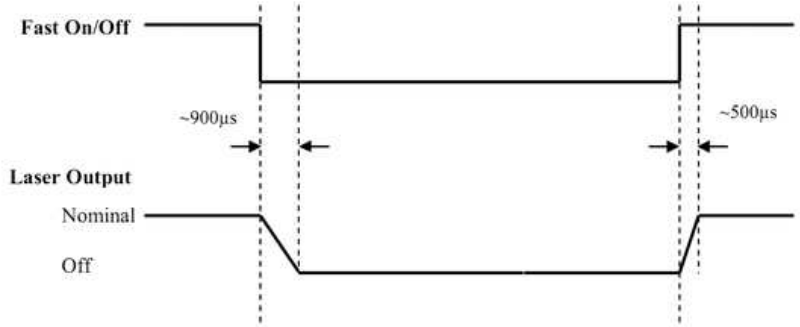
> **PicoFlash™ series**
> Up to >5W@1064nm
> Up to 40kW peak power
> Up to 140kHz rep.rate
> TEM00, M^2=1.05 typical

> **PicoSpark™ series**
> Up to >10W@1064nm
> Up to 200kW peak power
> Down to 750ps pulses
> TEM00, M^2=1.05 typ.

Making laser integration easier

- Development of OEM integration and process orientated functionnalities:
  - > **Output trigger** for synchronization with other equipments
  - > **Fast On-Off** functionality dedicated to high speed processing (scanners head)
  - > **Real time output energy control** for complex all-automated processing
  - > **Output security signals** for global laser safety management

Amplifier Fast On/Off diagram

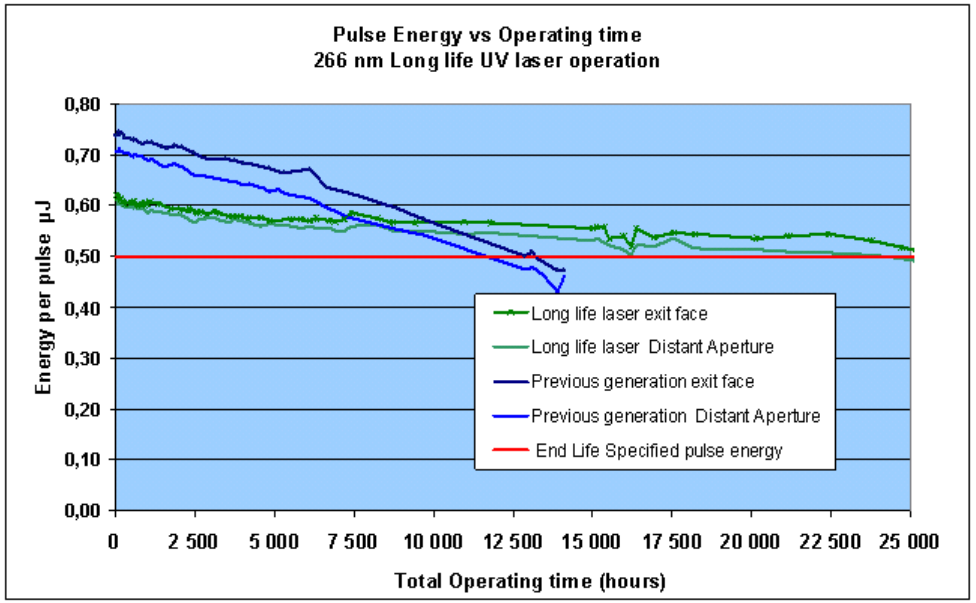


< 1ms rise time and fall time in Fast On-Off mode

Extending to shorter wavelentghs

- Intrinsic capacity to convert efficiently to **Deep UV** wavelengths thanks to high peak power
  - >**All Picolasers series** available down to **266nm**
  - >**PicoFlash™** series lasers available down to **355nm**
  - >High peak power PicoSpark™ lasers down to 532nm

- Design and know-how combine to provide over **25,000 hours of operation @266nm** for Picolasers



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3 – Added value for the process

Main features from the applicative point of view

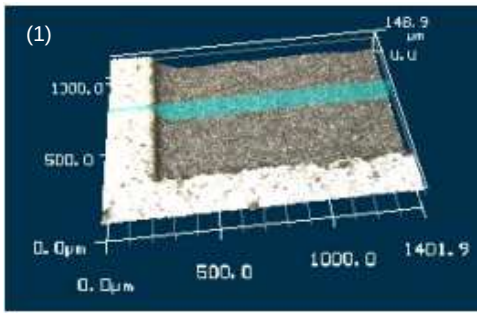
- Laser characteristics :
  - High peak power / Short pulse
  - UV wavelengths
  - Cost effective and reliable
  - Compact and air-cooled

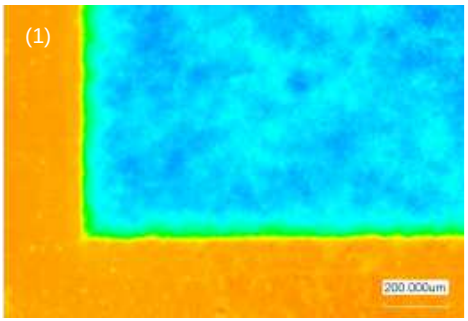
- Favourite playgrounds :
  - High resolution marking & scribing of virtually all materials
  - Controlled heat-input selective ablation processes
  - NL interaction driven processes (Supercontinuum, TPA)
  - UV or DUV applications
  - Industrial environment

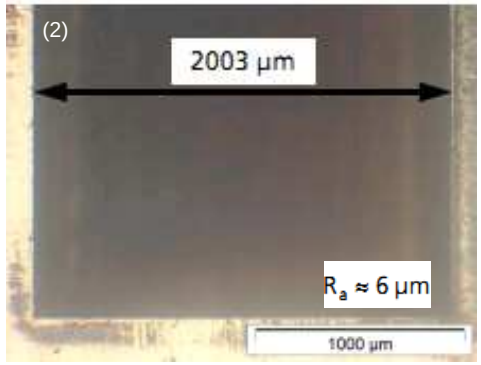
Hard materials processing capability

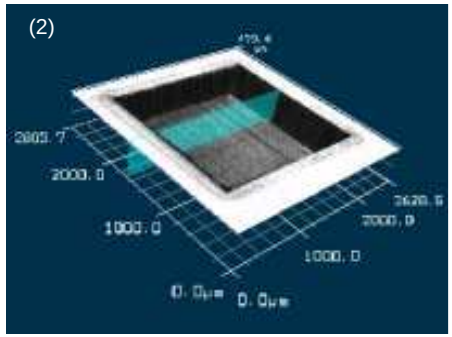
- Good surface quality and removal rate demonstrated for machinig oxydes, diamond-like structures, ceramics, hard metals..

- Applications / Markets:
  - > **Diamond, PCD, CVD** marking and scribing
  - > **Ivory, tooth, dental ceramics** machining
  - > **SiC** drilling
  - > Titanium layers selective ablation









- Key parameter : high peak power

(1) Dental ceramics machining (Image courtesy of ILT, Germany)

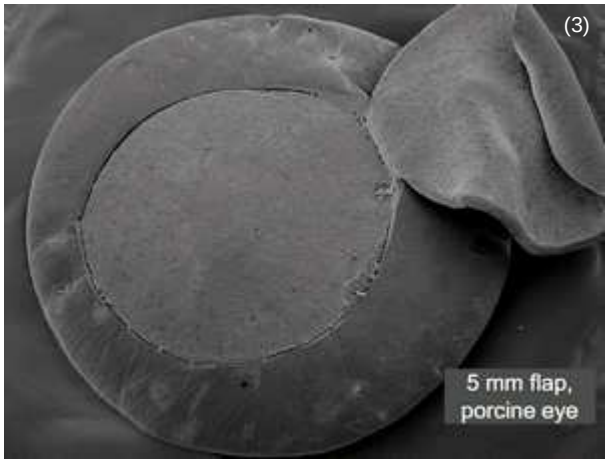
(2) PCD machining (Image courtesy of ILT, Germany)

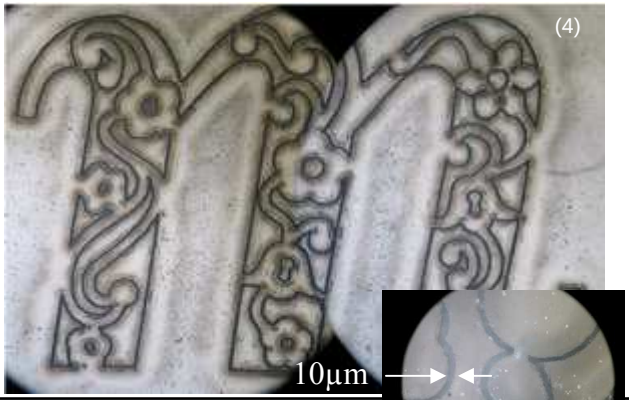
Transparent materials processing capability

- Thin glass plates cutting with µm-scale chipping
- Bulk marking with excellent repeatability proved in various structures (crystal, glass, plastic) – No µcracks

- Applications / Markets:
  - > Biomedical : **Lasik** surgery, cataract surgery
  - > **Glass plate cutting** for touch-screens or biological applications
  - > Bulk marking transparent plastics for **traceability** purpose (CR39, Polycarbonate,1.67)
  - > **Anti-counterfeit** semi-transparent bulk marking for watch glasses

- Key parameter : high peak power





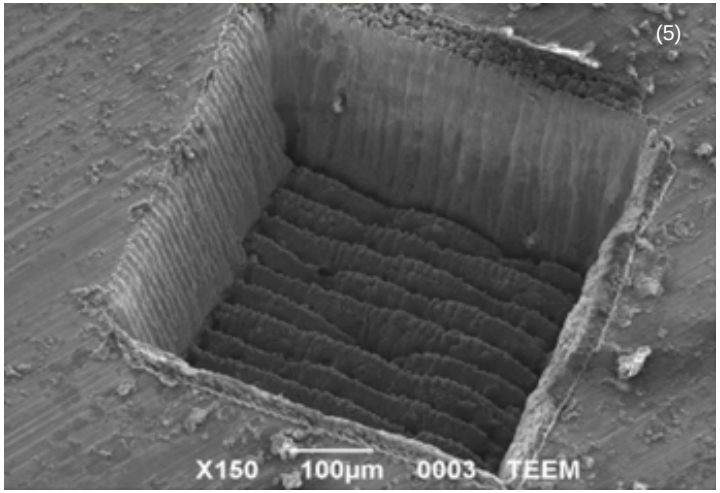
(3) Pig eye flap (Image courtesy of Luebeck university, Germany)

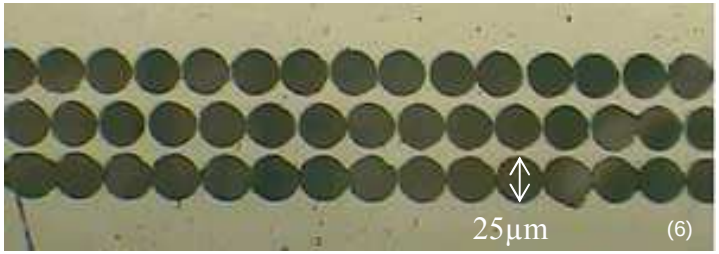
(4) Glass engraving (Musée de la dentelle, France)

Reflective material processing capability

- Micron-scale texturing thanks to low HAZ
- Marking on metals even at low energy

- Applications / Markets :
  - > **Surface texturing** of metals parts to reduce friction (PicoSpark™)
  - > **Fine scale scribing** of cast or injection moulds
  - > **Highly reflective** metals **plain marking**





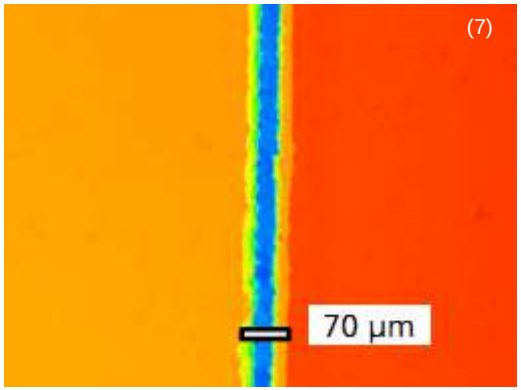
- Key parameter : high peak power

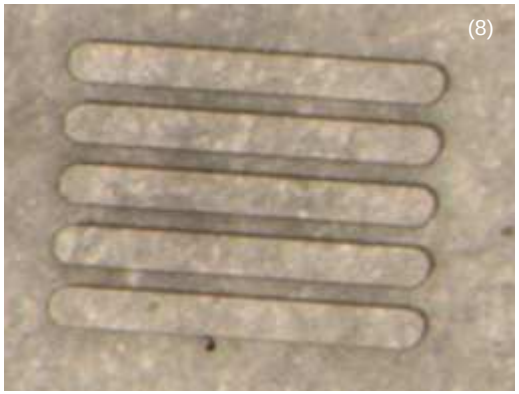
(5) Stainless steel machining

(6) Single-pulse marking on aluminium (6µJ only)

Controlled heat input micromachining

- Improved quality compared to ns lasers while conserving the economical figure
- Cost-effective alternative to ultrafast lasers or EDM
- Applications / Markets :
  - > Multilayers **selective removal** (ITO, LEP,…)
  - > **Electronics** : to manage increasing components density (PCB tracks correction, glue removal)
  - > **Polymers** 'cold' processing (polyimide, PET, polyurethane,..)
  - > Micromachining of **thin metal foils** (clock-making, micromechanics)
- Key parameter : short pulses





(7) Flex PCB cutting – Cut in 500µm thick polymide layer with 532nm (image courtesy of ILT, Germany)

(8) PET cutting – Cut in 15µm thick PET with 355nm (image courtesy of ILT, Germany)

Cost-effective UV solutions

- For industrial environment
- Can reduce the COO of excimer lasers based processes

- Applications / Markets :
  - > Photoluminescence (**UVLED wafer** testing, LIF)
  - > **Biomedical** (µ-dissection)
  - > **PCB** repair
  - > **LCD/FPD** panel repair
  - > **Excimer** lasers replacement market

- Key parameters : cost efficiency, high peak power

(9) Laser-induced fluorescence (Courtesy of Kinzle, Germany)

(10) Micro-dissection of biological tissue (Courtesy of mmi, Germany)

4 – Conclusion and perspectives

Conclusion and perspectives

Picolasers can offer picosecond class laser solutions at nanosecond economics

- Market evolutions seem to be increasingly pointing towards such laser solutions
- Qualified applications fields continuously expanding, with a wide range of segments already penetrated so far :
  - > Eye surgery with flap making
  - > Photovoltaics with CIGS cell patterning
  - > Electronics and displays with PCB, LCD and FPD repair
  - > More to come…

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Thank you!