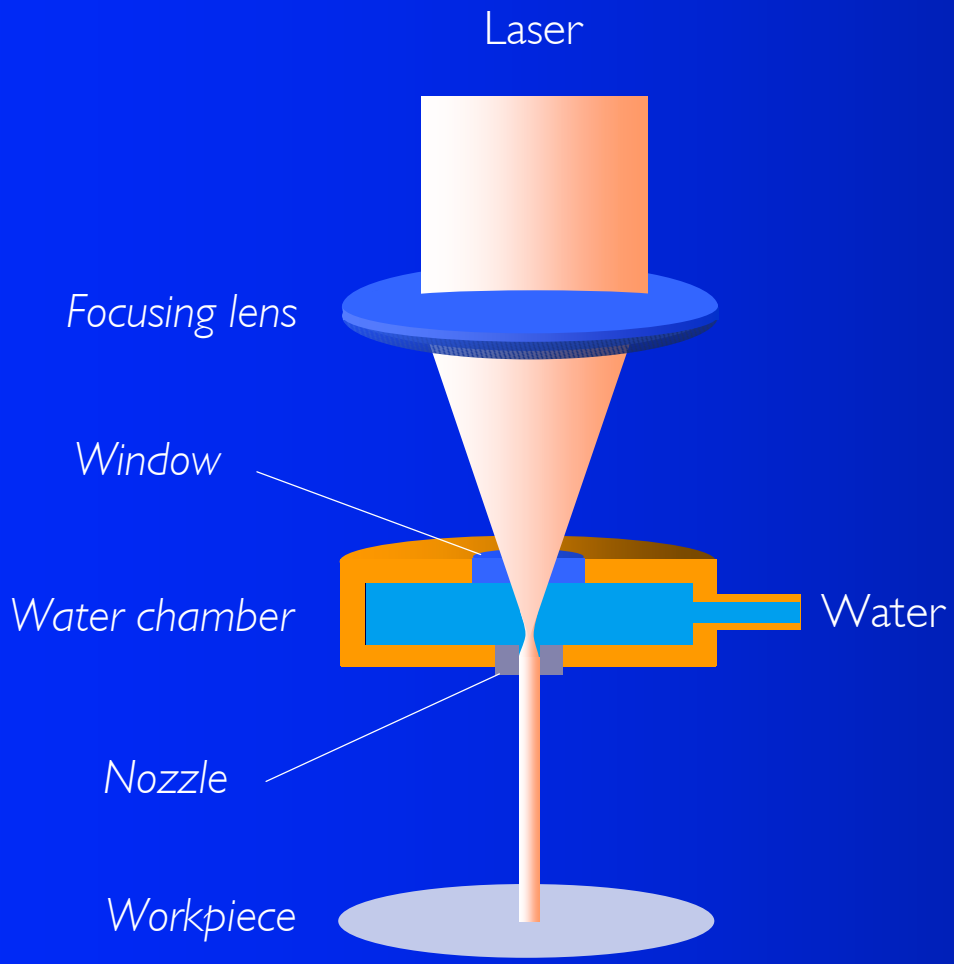
Water Jet-Guided Laser
Laser-Microjet®

SYNOVA

Innovative Laser Systems

The Principle



High pressure water is forced through a nozzle creating a thin water jet.

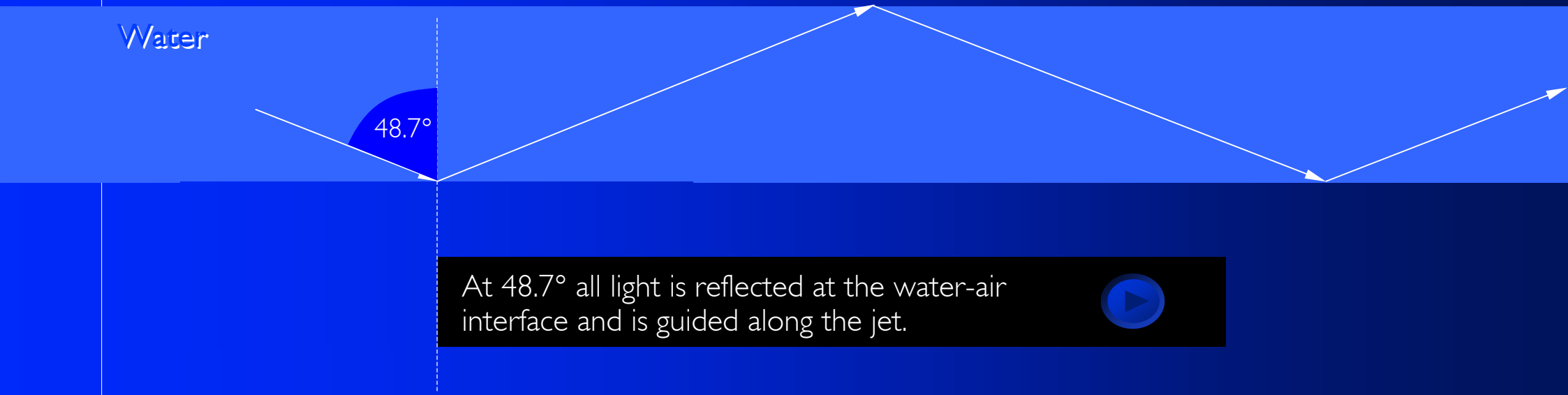
The laser beam is focused through the water chamber into the nozzle.

Leaving the nozzle, the laser beam is guided inside the water jet by total reflection at the water-air interface.

Total Reflection

The water jet is a liquid fiber of variable length.

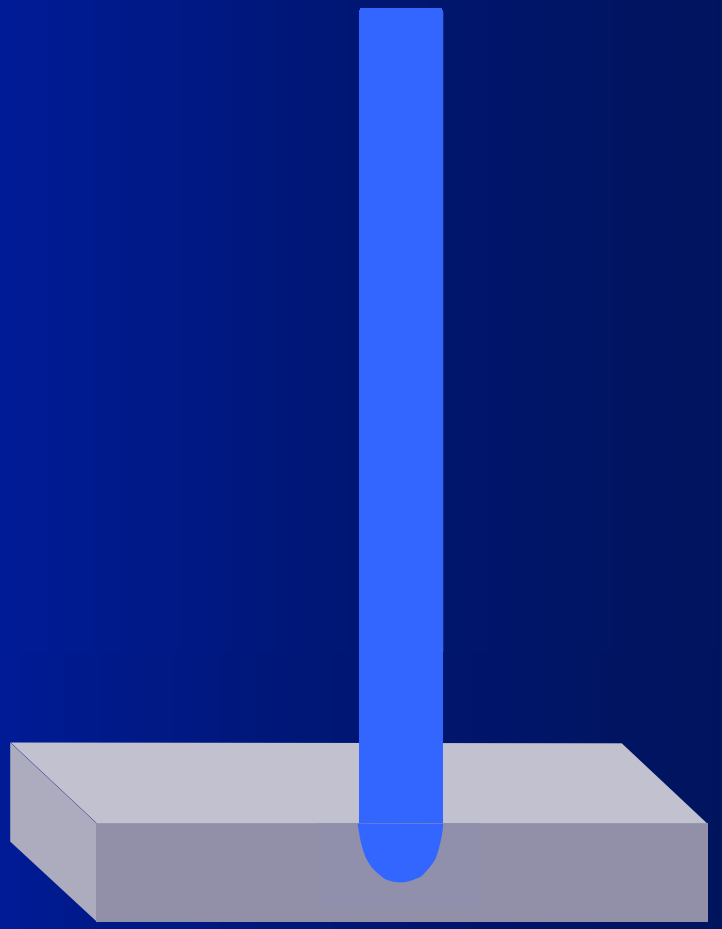
The light arriving at the water-air interface
is reflected and transmitted.
The direction and intensity of the resulting rays
depend on the angle of incidence.



At 48.7° all light is reflected at the water-air interface and is guided along the jet.

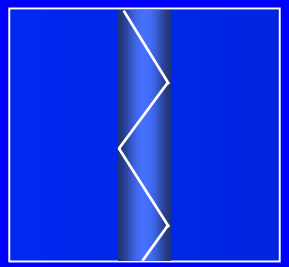
The Ablation Process

1. The water jet is directed onto the workpiece.
2. The laser pulse is guided to the surface of the workpiece.
3. The laser pulse is absorbed by the material.
4. The absorbed laser energy generates a plasma on the surface separating water and workpiece.
5. The material, which absorbs the laser beam melts or vaporizes.
6. At the end of the laser pulse, the plasma disappears and only the water jet contacts the surface.
7. The water jet expels the molten material.
8. Before the next pulse is emitted, the water jet removes any heat induced in the material during the laser ablation.

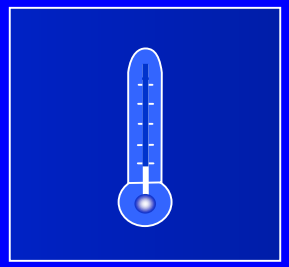


The Functions of the Water Jet

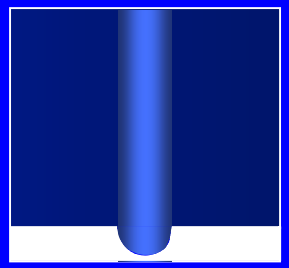
The water jet works as a fiber for guiding the laser beam



The water jet cools the work piece during laser ablation



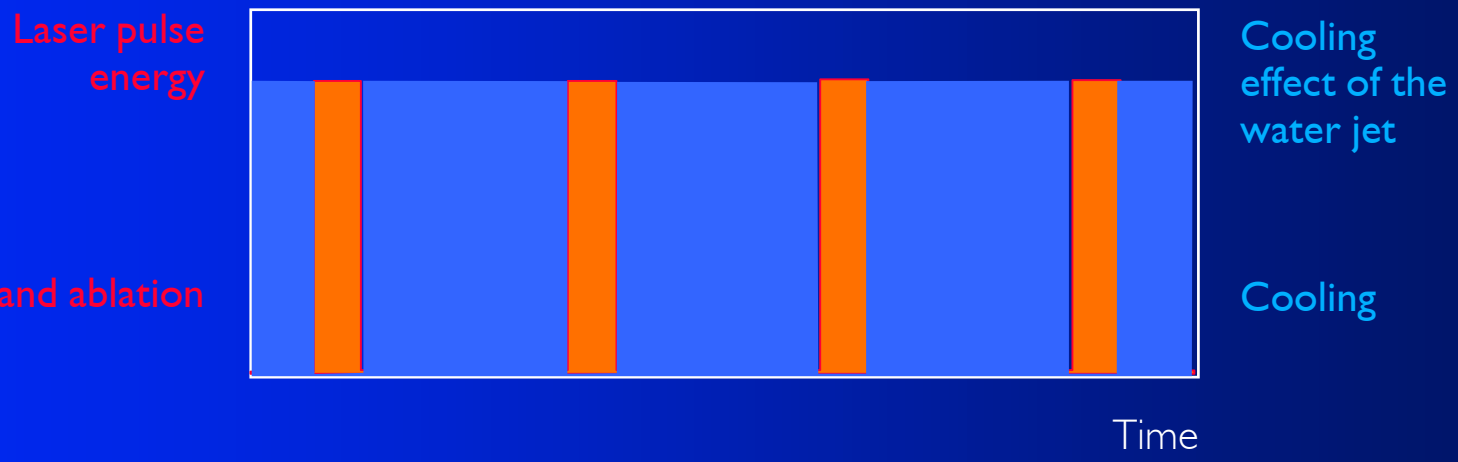
The water jet removes the molten material



The water jet is **not** abrasive. The material is ablated only by laser.

The Cooling

The pulsed mode of the laser ensures continous alternation of heating (during laser pulse) and cooling (between laser pulses)



The result is a heat damage-free material ablation

The problem of heat damage (micro cracks, structural changes) inherent in any laser ablation process is prevented by the water jet

The Water Jet

The liquid used is de-ionized, filtered water.

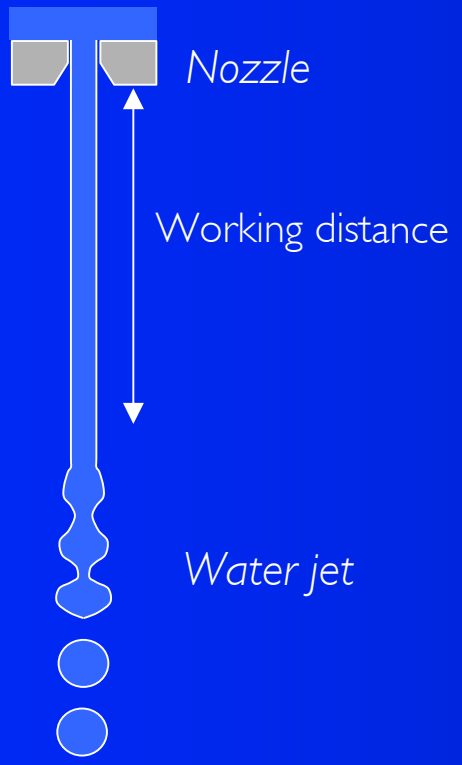
water pressure: 20-500 bars	The pressure value depends on the actual application. The resulting force acting on the work piece is very small, smaller than the force due to the cutting gas of conventional lasers.
water jet speed: up to 300 m/s (500 bars)	The high speed ensures fast removal of debris.
water jet diameter: 40, 50, 60, 75 or 100 microns	The specially designed nozzles are made of diamond or sapphire. The time for changing the nozzle and laser beam alignment is about 10 min. The nozzles do not wear out, they can only be damaged by misaligned laser beam.
water flow rate: 5-100 ml/min	The water flow rate is very small. For example, a 50 micron nozzle consumes only about 20 ml/min at 300 bars.

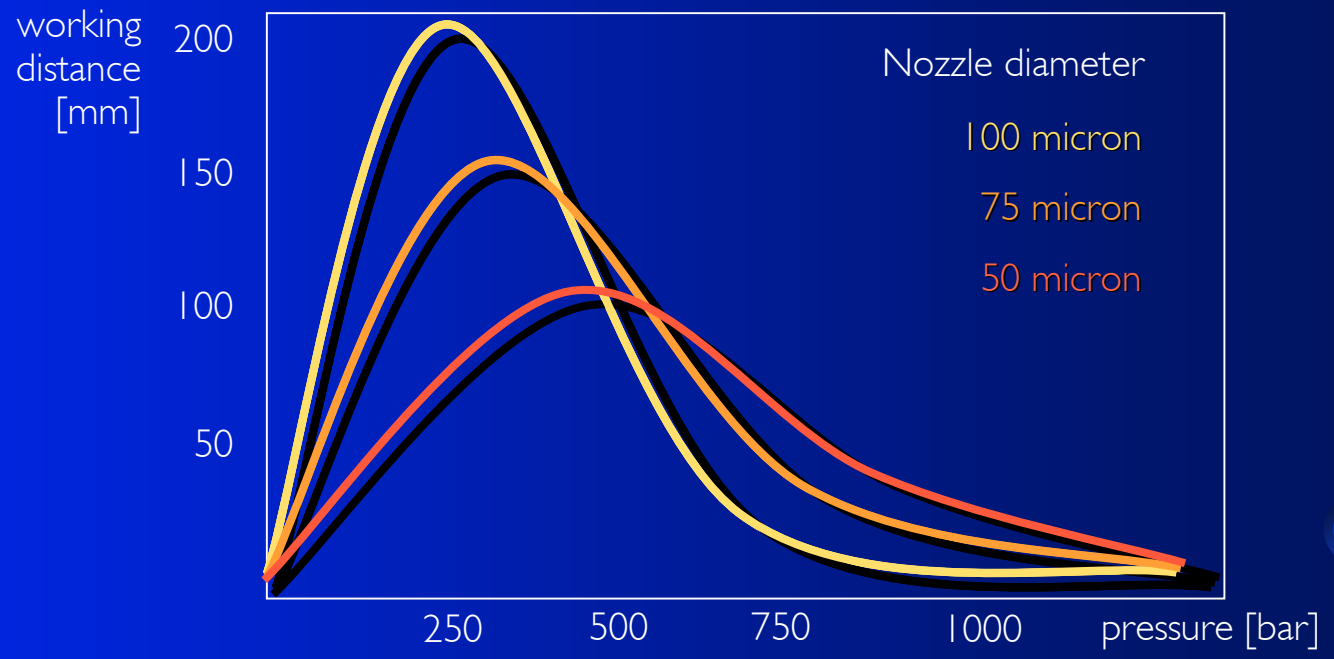
Working Distance

The working distance corresponds to the length of the water jet which is cylindrical and useable for laser beam guiding (= coherent length)

Inside this working distance, the water jet, and therefore the laser beam as well, have a constant diameter.

Behind the stable length, the water jet no longer has a cylindrical shape and falls into drops. The laser beam leaves the water jet in a diffusive manner making a material ablation impossible.





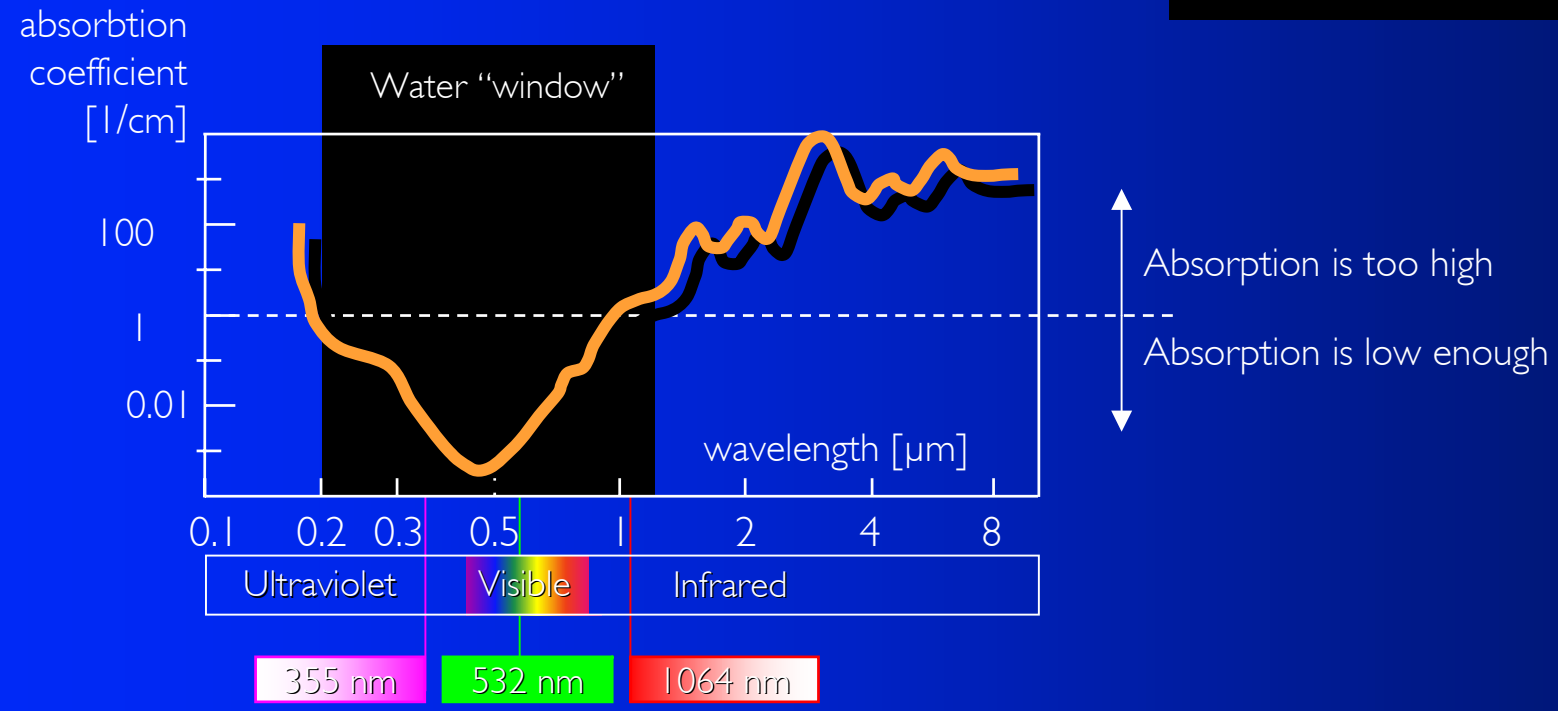
The Laser

Useable wavelengths are limited to the range, in which the absorption by water is low (absorption coefficient < 1/cm).

Thus, possible wavelengths are between 200 nm and 1100 nm.

Lasers from UV to near-infrared are used. Mainly solid-state lasers.

The most powerful is the Nd:YAG at the fundamental frequency (1064 nm). Besides this type, frequency-doubled (532 nm) and -tripled Nd:YAG (355 nm) lasers are used.



Technical Data of the Laser

Wavelength

	1064 nm	532 nm	355 nm
Average power	200 W	100 W	10 W
Pulse type	short, long	short	short

Pulsed lasers are used due to alternated heating and cooling.

The pulse duration is a function of the application. The short pulses are obtained with switched continous-wave (CW) lasers. The long pulses are obtained with flashlamp pumped lasers.

Diode- or lamp pumped lasers, depending on the requirements of the application.

Pumping

	diode	lamp
Lifetime	5,000 – 10,000 hours	500 – 1,000 hours
Exchange cost	30,000 €	600 €

Laser pulse

	short	long
Pulse duration	0.1 – 1 µs	10 – 100µs
Repetition rate	10 – 50kHz	0.5 – 2kHz
Pulse energy	1mJ	200mJ

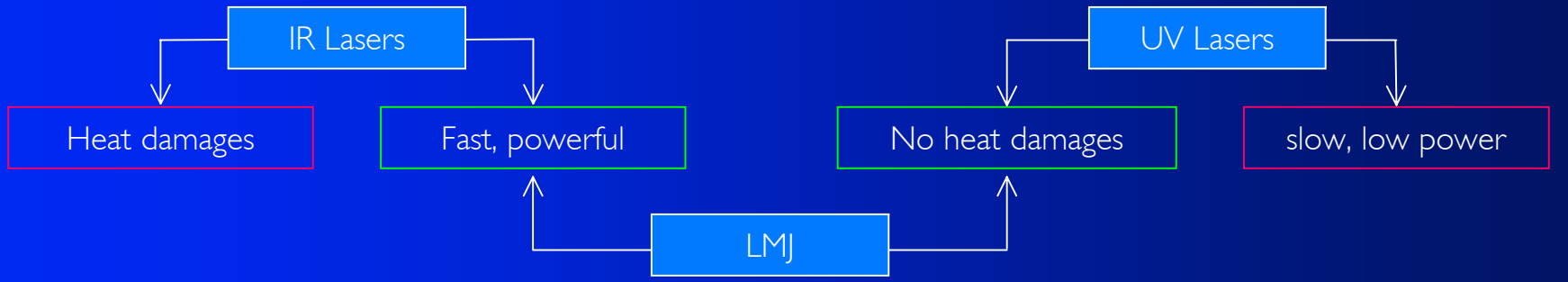
Comparison with Conventional Laser

The laser became in the last two decades a precise, fast, wear-less, flexible tool, used for cutting, drilling, marking and welding. Many of today's production processes are unimaginable without the laser.

Nevertheless, in some applications, as for example in the electronic or medical field, the laser is still too imprecise, too slow, or unacceptable, because of material damages.

The dilemma is caused by high-power infrared lasers, widely used in industrial material processing, but too « hot », creating heat damage and debris.

Meanwhile, shorter wavelengths found in UV lasers create less heat and debris, lack power for efficient material processing.



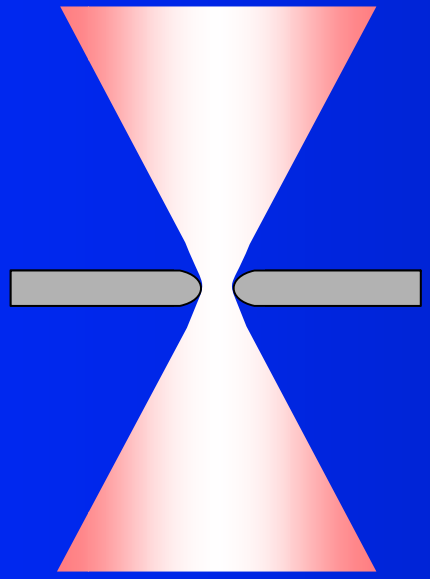
The solution is the water jet guided laser (LMJ), because it transforms a « hot » infrared laser into a « cool » laser, avoiding any heat damage. The LMJ combines therefore high ablation efficiency, speed, precision, quality while avoiding material damage.

Laser Beam Shape

In conventional laser cutting, the laser beam is focused on the work piece. Only in the focal point is the laser intensity high enough for material ablation.

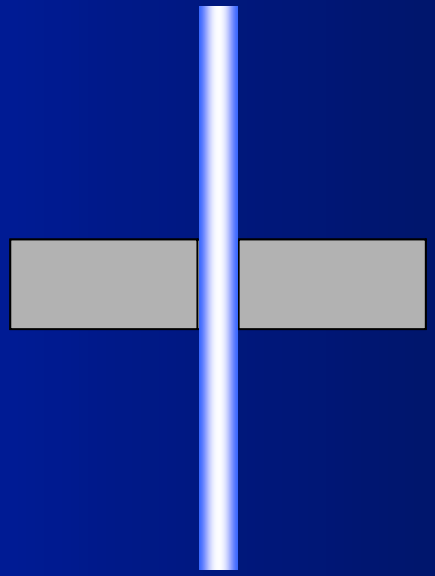
In the case of the Laser-Microjet, the laser beam is parallel and the laser intensity is constant over several centimeters.

Conventional Laser



Divergent Laser Beam

Laser-Microjet



Parallel Laser Beam

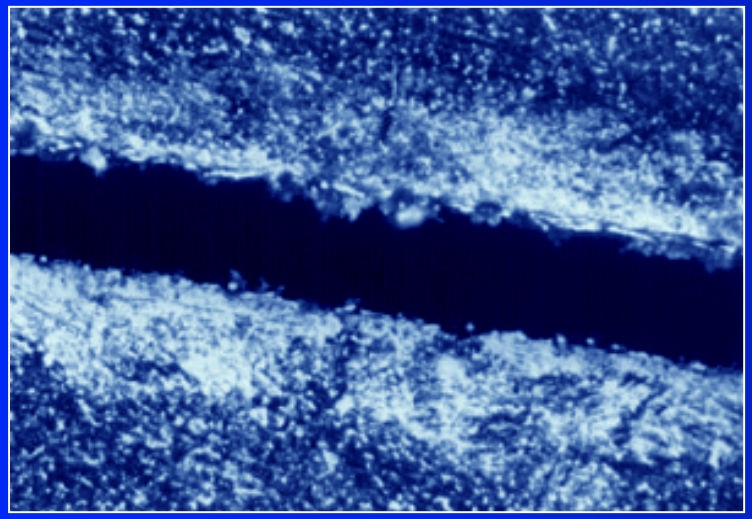
Advantages of the Water Jet Guided Laser

No heat damages,	because the water jet cools the cutting edges.
No burrs, no slag,	because the water prevents slag deposits.
No fixed working distance	because the laser beam diameter is constant.
No need of cutting gas,	because the water jet expels the molten material.
Low air dust,	because the cutting waste is absorbed by the water.
Parallel and narrow cutting kerfs,	because the water jet guides the laser beam inside the material as well.
Cuts faster,	because the water jet is much more efficient in the material expulsion than the gas jet used in conventional laser cutting.
Lower forces on the material,	because the force resulting from the water jet is much lower than the force generated by the cutting gas.
Work pieces can be cut on **adhesive tapes,**	because the ablated material is immediately cooled by the water jet.
Multi-layer material can be cut,	because the water jet is able to guide the laser through a layer.

Example

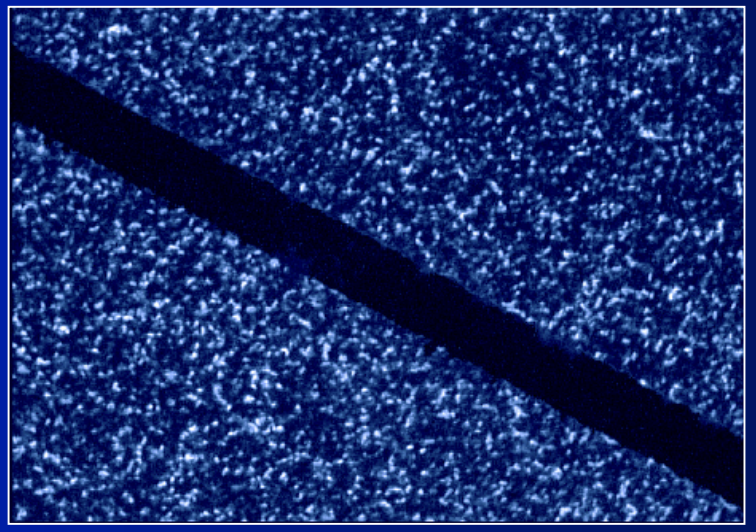
Silicon wafer

Conventional Laser



- Burrs
- Deposits
- Heat damage

Laser-Microjet



- No burrs
- No deposits
- No heat damage

The Water Jet Guided Laser