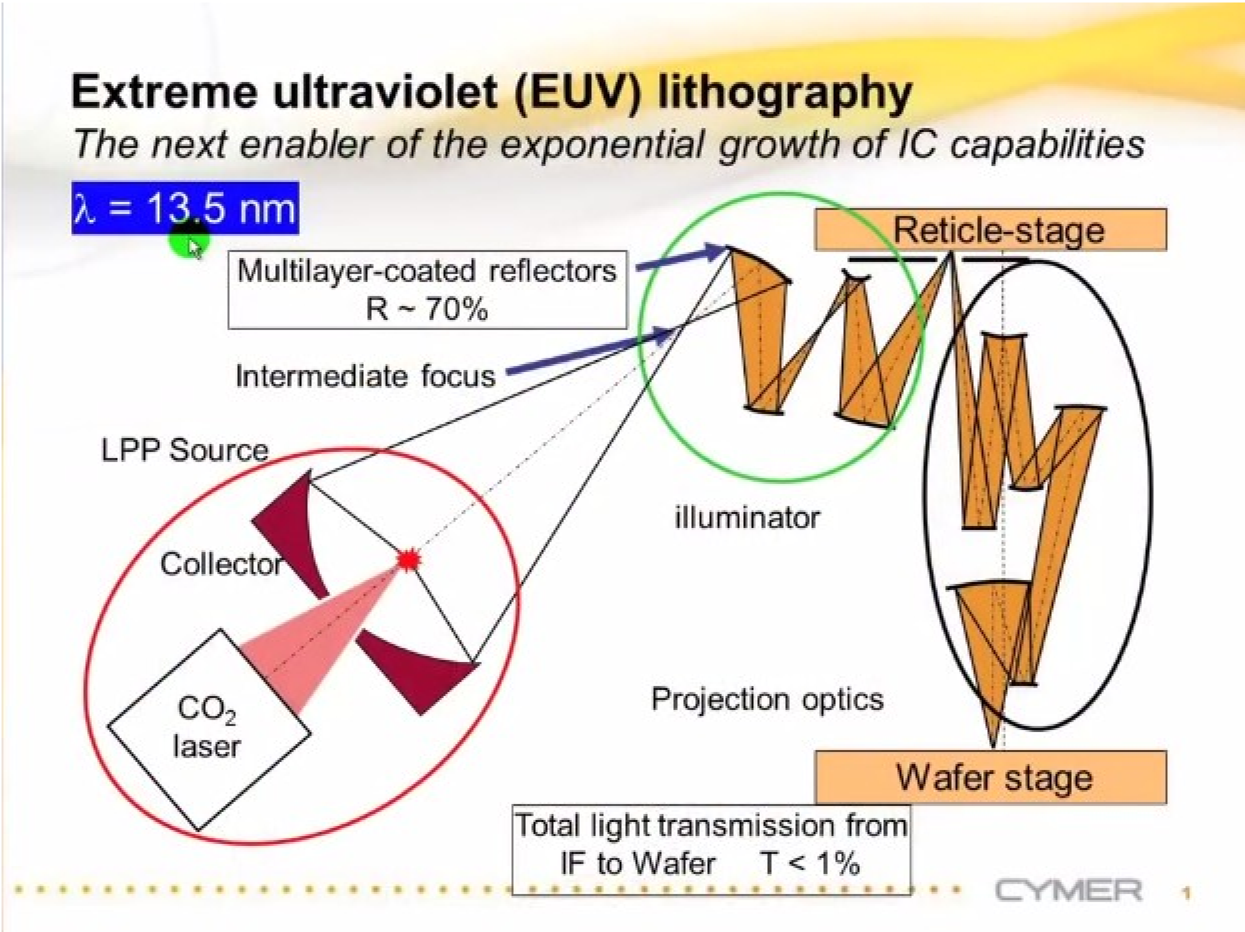
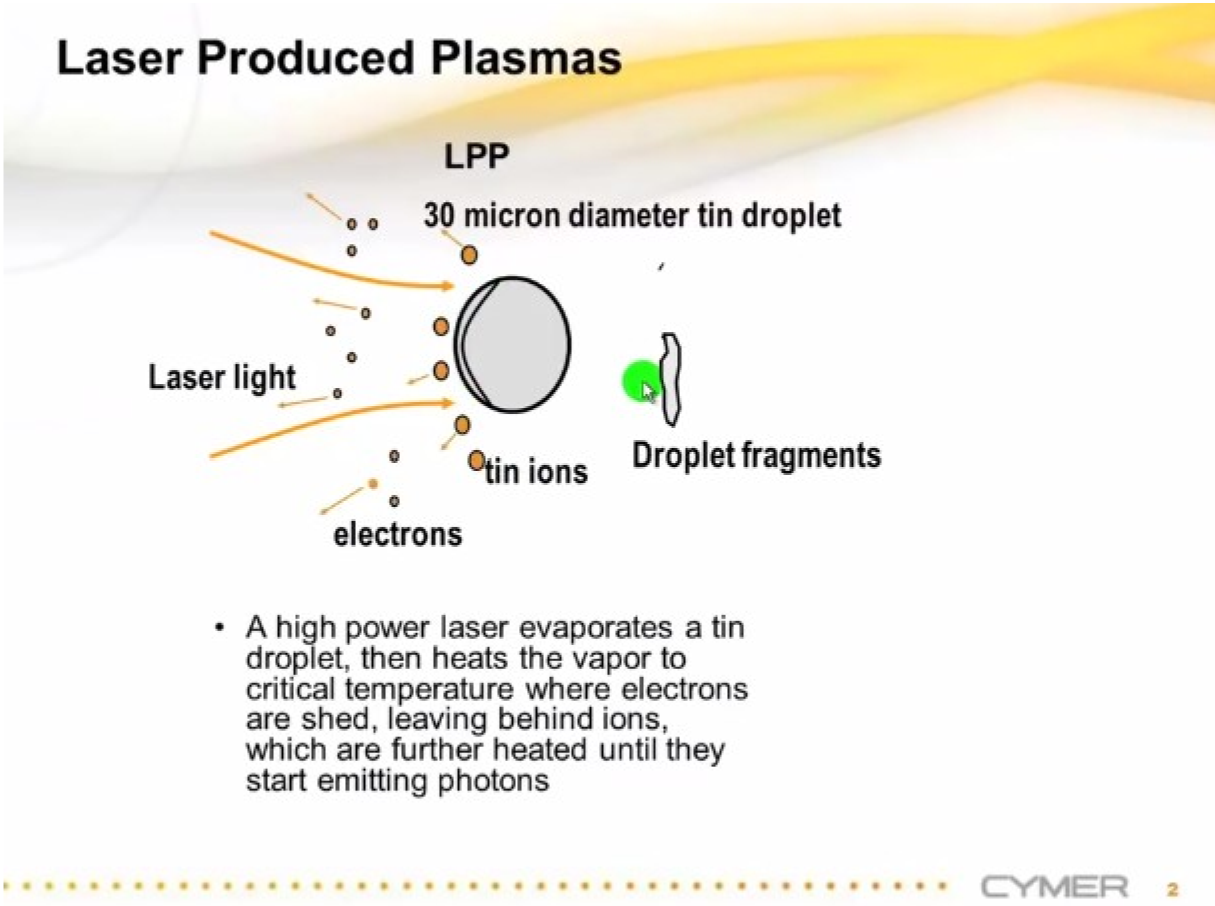
EUV Lithography Cymer light source.



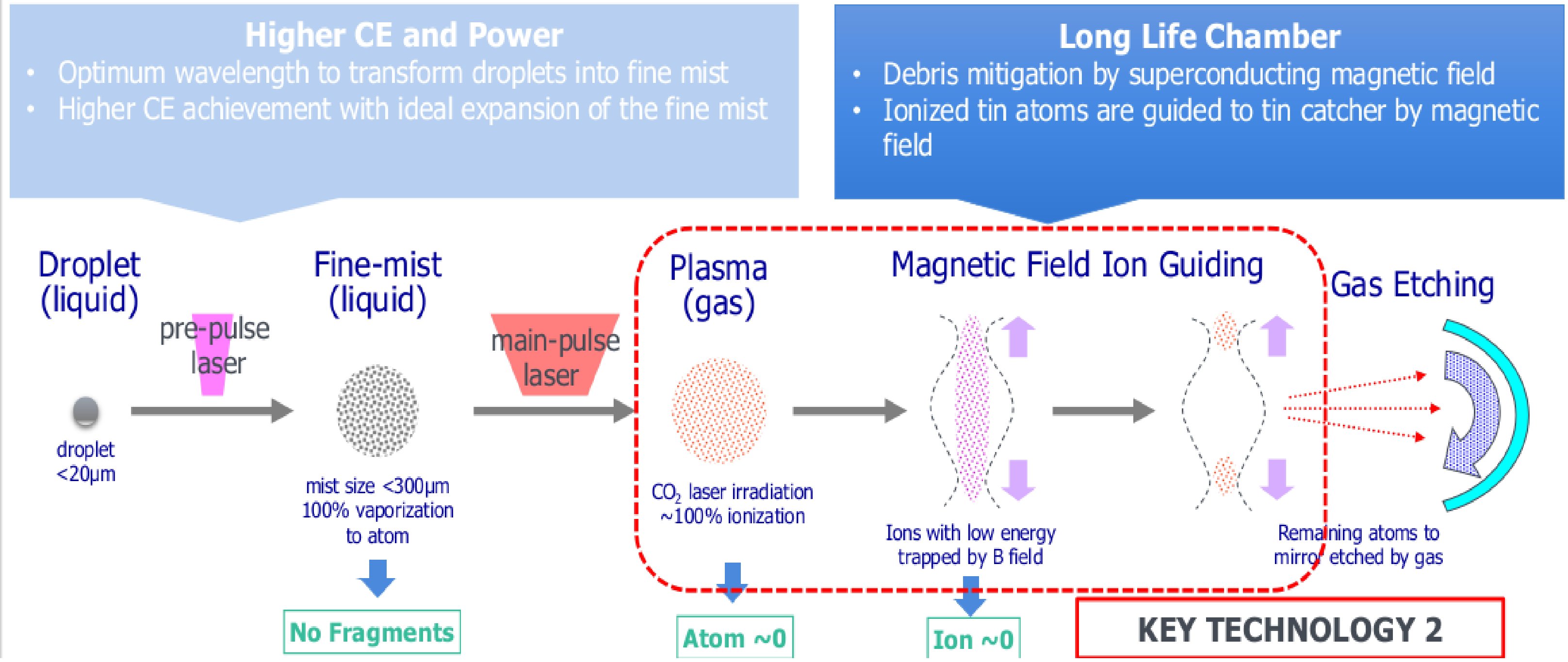
13.5nm short wavelength, light go through optics will lose intensity. The transmission is low, less than 1%.   So the minimal power needed for 13.5nm at least 100Watts.

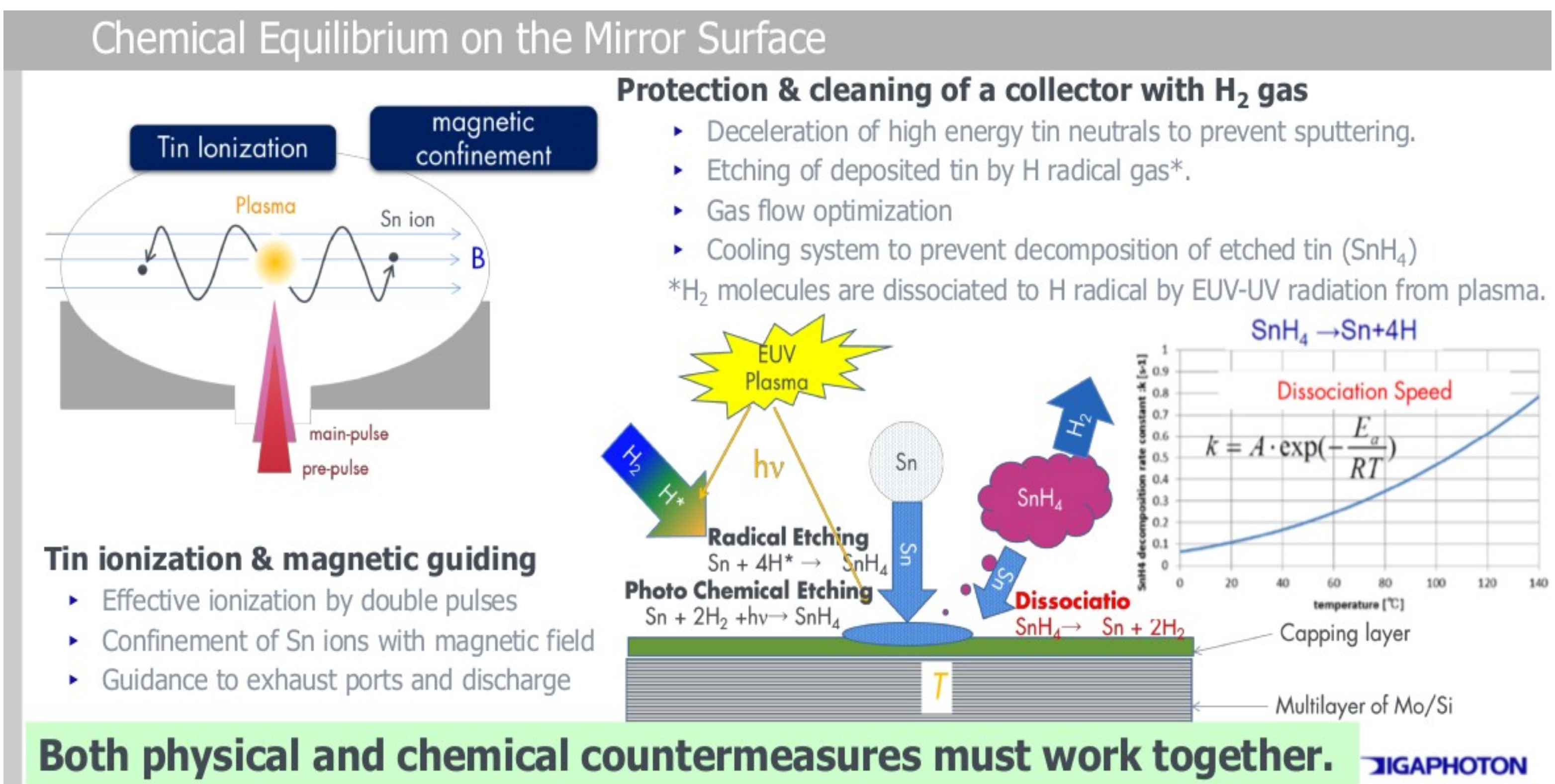
Tin

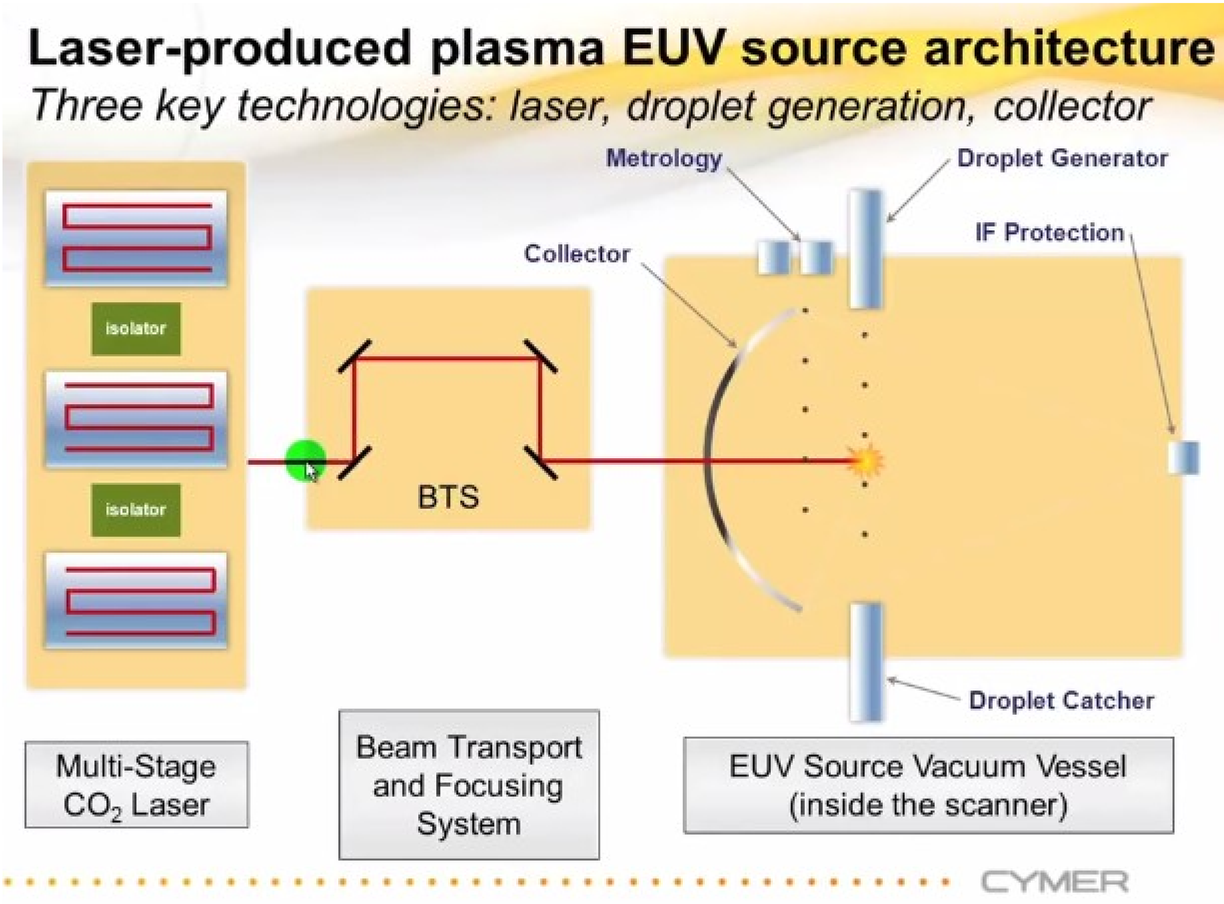


efficient generator of 13.5nm light.
Form dense plasma, illuminated by CO_2 laser . That plasma on the order 30eV excites the tin atoms.
some of those droplet fragments are collected in the vessel.
The electrons from tin atom and tin ions are mitigated and diverted away from the collector.

The temperature of the plasma reaches 500,000 degree C.


Higher CE and Power
Optimum wavelength to transform droplets into fine mist
Higher CE achievement with ideal expansion of the fine mist
Long Life Chamber
Debris mitigation by superconducting magnetic field
Ionized tin atoms are guided to tin catcher by magnetic field
Droplet (liquid)
pre-pulse laser
droplet <20μm
Fine-mist (liquid)
mist size <300μm
100% vaporization to atom
No Fragments
main-pulse laser
Plasma (gas)
CO_2 laser irradiation
~100% ionization
Atom ~0
Magnetic Field Ion Guiding
Ions with low energy trapped by B field
Ion ~0
Gas Etching
Remaining atoms to mirror etched by gas
KEY TECHNOLOGY 2


Chemical Equilibrium on the Mirror Surface
Tin Ionization
magnetic confinement
Plasma
Sn ion
B
main-pulse
pre-pulse
Tin ionization & magnetic guiding
Effective ionization by double pulses
Confinement of Sn ions with magnetic field
Guidance to exhaust ports and discharge
Protection & cleaning of a collector with H_2 gas
Deceleration of high energy tin neutrals to prevent sputtering.
Etching of deposited tin by H radical gas*.
Gas flow optimization
Cooling system to prevent decomposition of etched tin (SnH_4)
*H_2 molecules are dissociated to H radical by EUV-UV radiation from plasma.
EUV Plasma
H_2
H*
hν
Sn
SnH_4
Radical Etching
$Sn + 4H^* \rightarrow SnH_4$
Photo Chemical Etching
$Sn + 2H_2 + h\nu \rightarrow SnH_4$
Dissociatio
$SnH_4 \rightarrow Sn + 2H_2$
T
Capping layer
Multilayer of Mo/Si
$SnH_4 \rightarrow Sn+4H$
Dissociation Speed
$k = A \cdot \exp(-\frac{E_a}{RT})$
temperature [℃]
Both physical and chemical countermeasures must work together.
GIGAPHOTON



Consists of 3 parts

1)Infrared Laser Drive system. Its huge system and generally not part of the stepper/Scanner and placed in the sub fab area. The laser light is about 10um in wavelength and 20kilowatts when entering the BTS. The Drive system is not part of the stepper/Scanner physcially.

2)BTS (Beam Transport and Focus system) consists of Turning mirror and sealed beam tube.

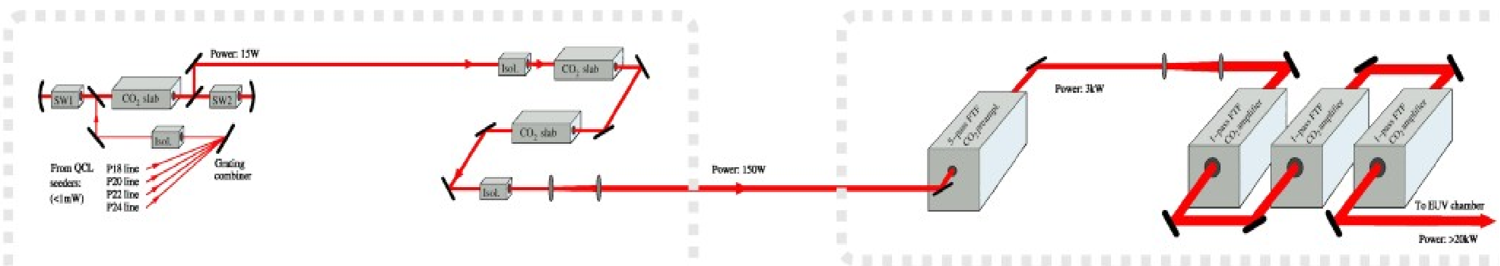
3)EUV source Vaccum Vessel consists of droplet generator(tin) and Catcher and Collector, which direct the EUV light to the IF(Intermediate focus) that connects to the stepper/scanner. The Source Vessel integrated inside the stepper/scanner as single unit.

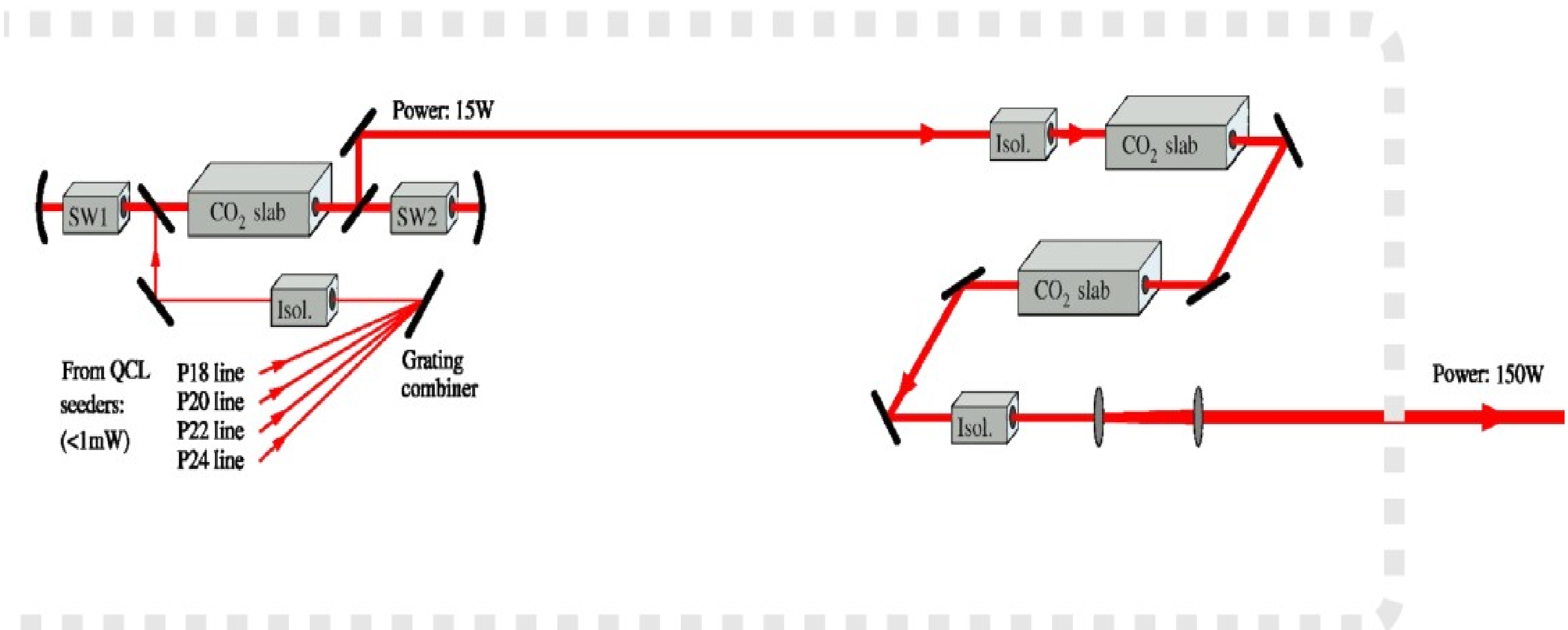
HYBRID CO2 LASER SYSTEM

The CO 2 laser driver must generate pulses of a duration <20ns required for best efficiency of the LPP process, and must
deliver >200mJ of energy per pulse at a repetition rate of 100kHz. The only way to meet this >20kW average power
requirement is to use master-oscillator-power-amplifier (MOPA) approach. It is well known that an

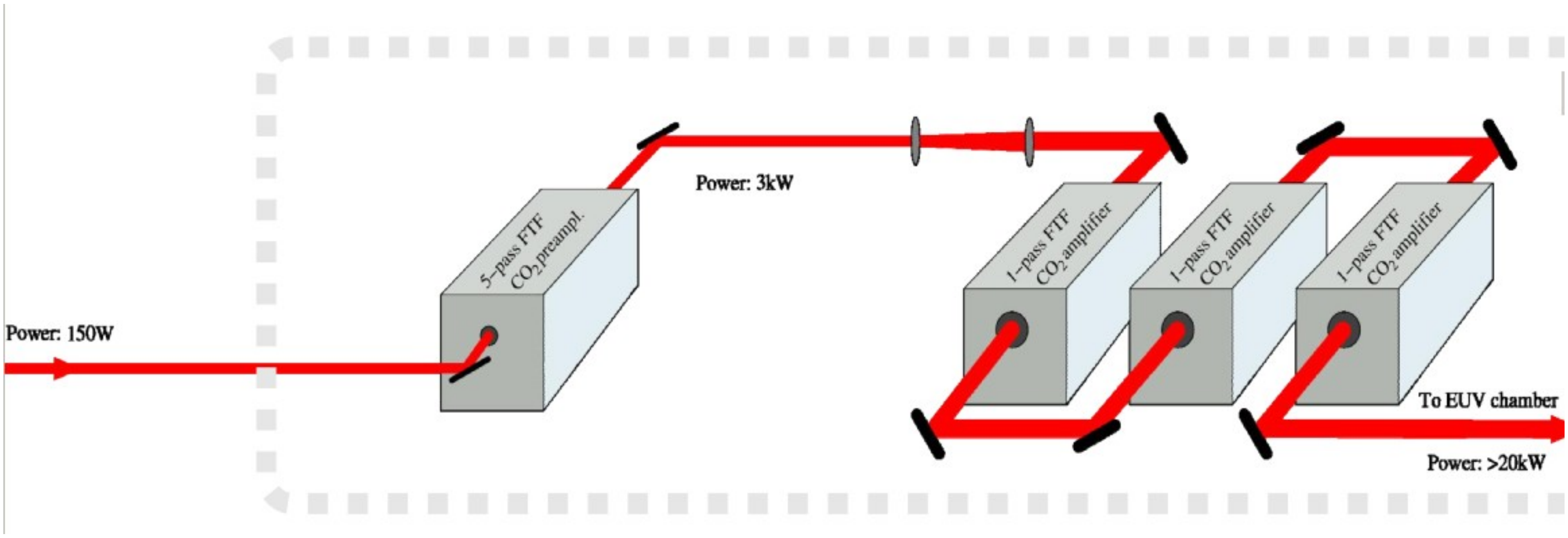
amplification of
pulses with duration comparable to the relaxation dynamics of the CO_2 medium is significantly less efficient as
compared to a CW operation. For this reason we have developed a multi-line capable master oscillator that can
ameliorate the problem of reduced efficiency of pulsed amplification.

The configuration of high power, pulsed CO_2 laser system is presented





Zoomed-in <u>Multiline Oscillator</u> section



Zoomed-in POWER AMPLIFIER section

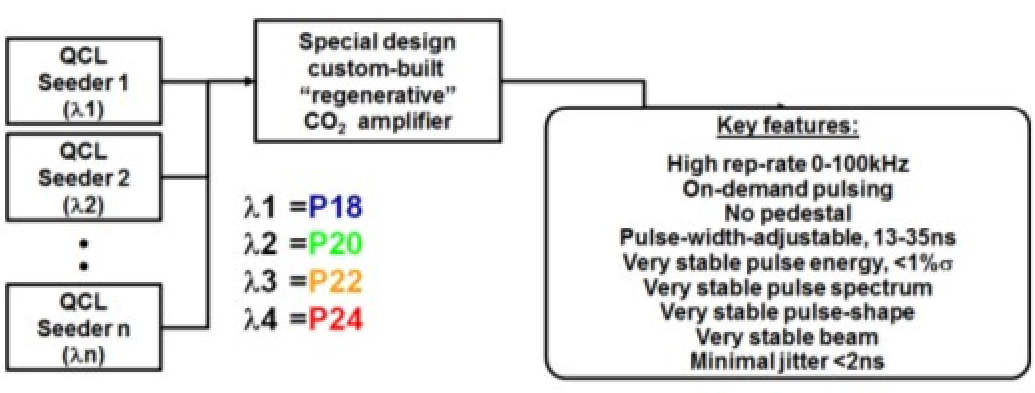
The multi-line oscillator was custom-designed especially to deliver the required pulse format. This

innovative device combined the RF-discharge-excited, slab-waveguide CO 2 laser technology with the relatively recent,
solid-state, quantum-cascade lasers (QCL) used as seeders.

This marriage enabled a robust generation of pulses of
excellent stability and duration adjustable within 15-35ns. The multi-line operation was also implemented by combining
four QCLs addressing P-branch lines P18-P24 of regular band of CO 2 molecule (10.6 um).

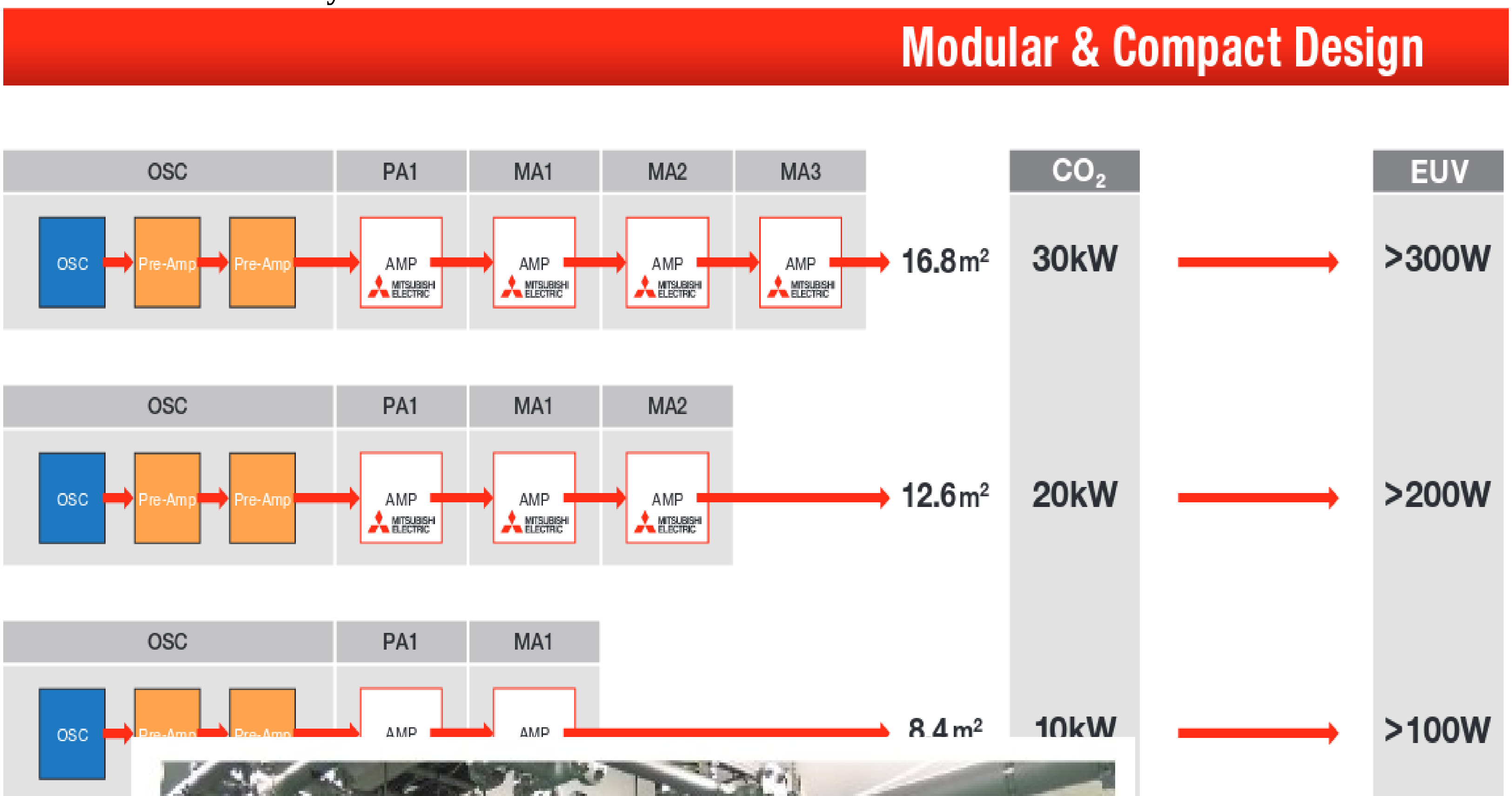
that simultaneous amplification on these 4 strongest lines was expected to bring up to 20% energy improvement as
compared to amplification on a single line only. The oscillator power was boosted to about 100W by a system of two,
multi-pass amplifiers built also on RF-discharge-excited, slab-waveguide CO 2 lasers.
The power amplifier stage of the MOPA system consisted of pre- and main amplifiers. The task of the power pre-
amplifier was to boost 100W of master oscillator output to the level required for an efficient driving of power amplifier

stages.
The power stages employed multi-kW, commercial RF-discharge-excited, fast-flow CO 2 lasers. In the Proto systems, fast-axial-flow (FAF) lasers

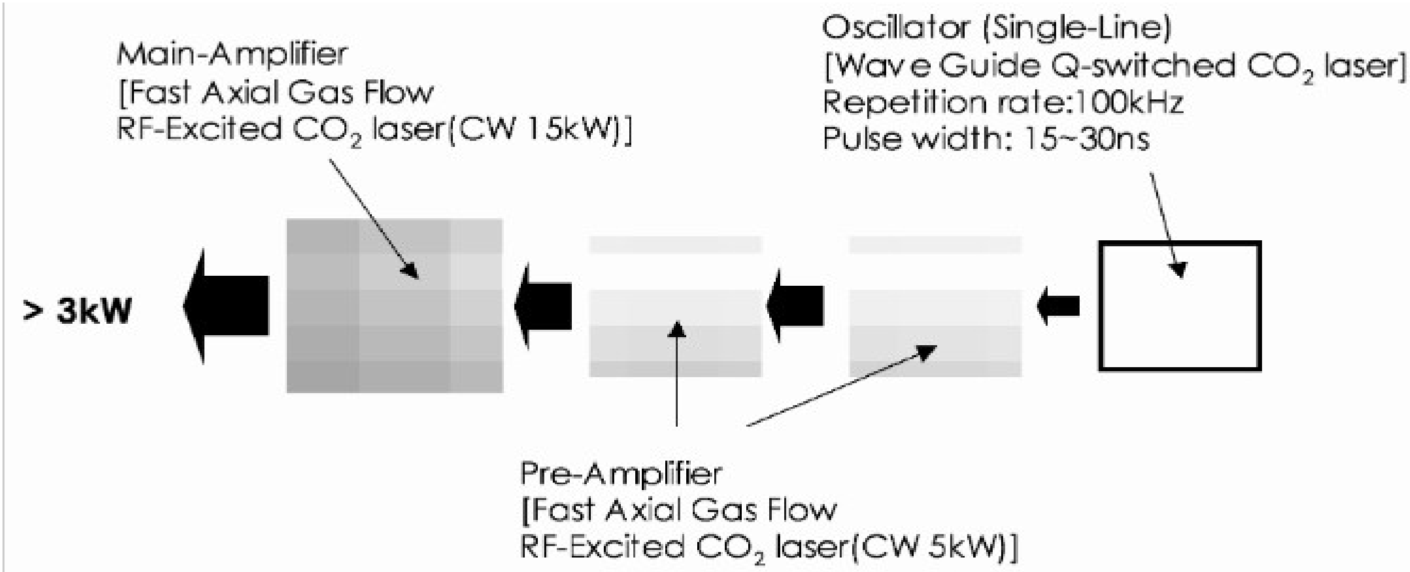


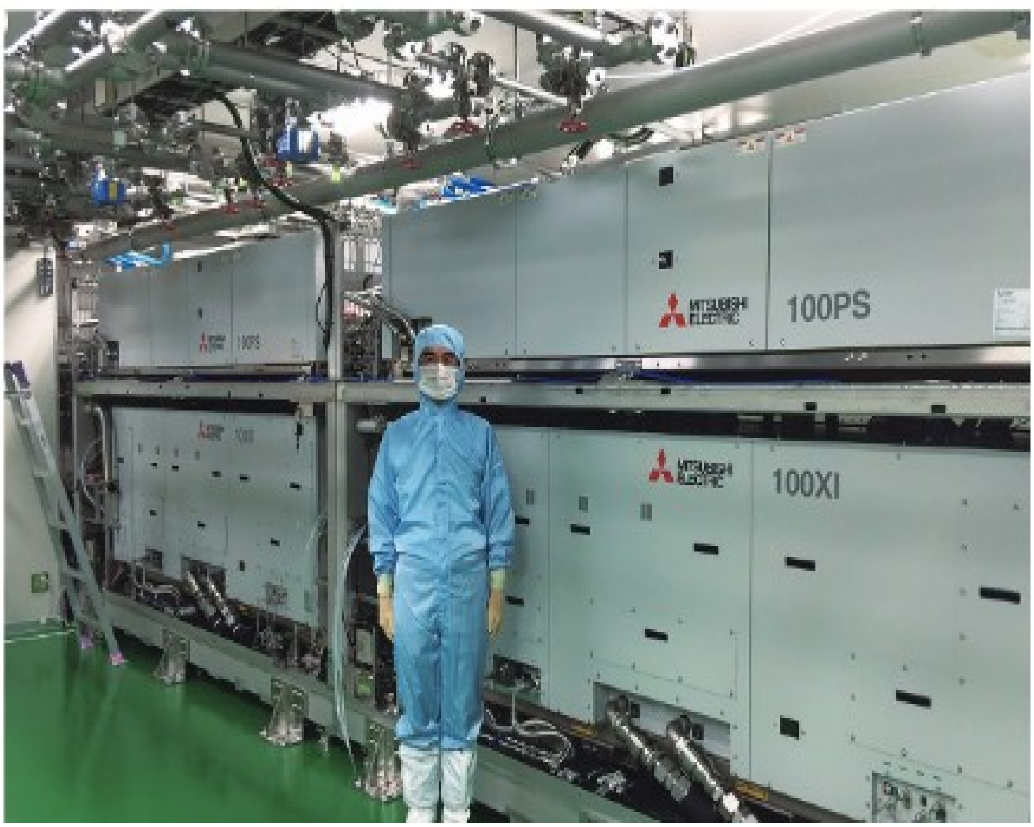
were used as main amplifiers. Recent developments in collaboration with
Mitsubishi Electric Co. have allowed us to use also the fast-transverse-flow (FTF) lasers, which have got a number of
advantages over FAF ones, such as a possibility to arrange multi-passing. An effective preamplifier based on multi-
passed FTF laser. Higher power output and slightly improved beam quality are expected from this system.

Laser Drive System



Oscillator





Laser   Drive System

Lasers

Two types of CO_2 laser amplifiers have the capacity of providing high power for high volume manufacturing EUV source. One is (fast-) axial-flow CO_2 laser and the other is transverse-flow one. Both types are now commercially available as laser oscillators for material processing including metal cutting and welding. The parameter study is described here between commercial high-power transverse-flow and axial-flow CO_2 lasers.

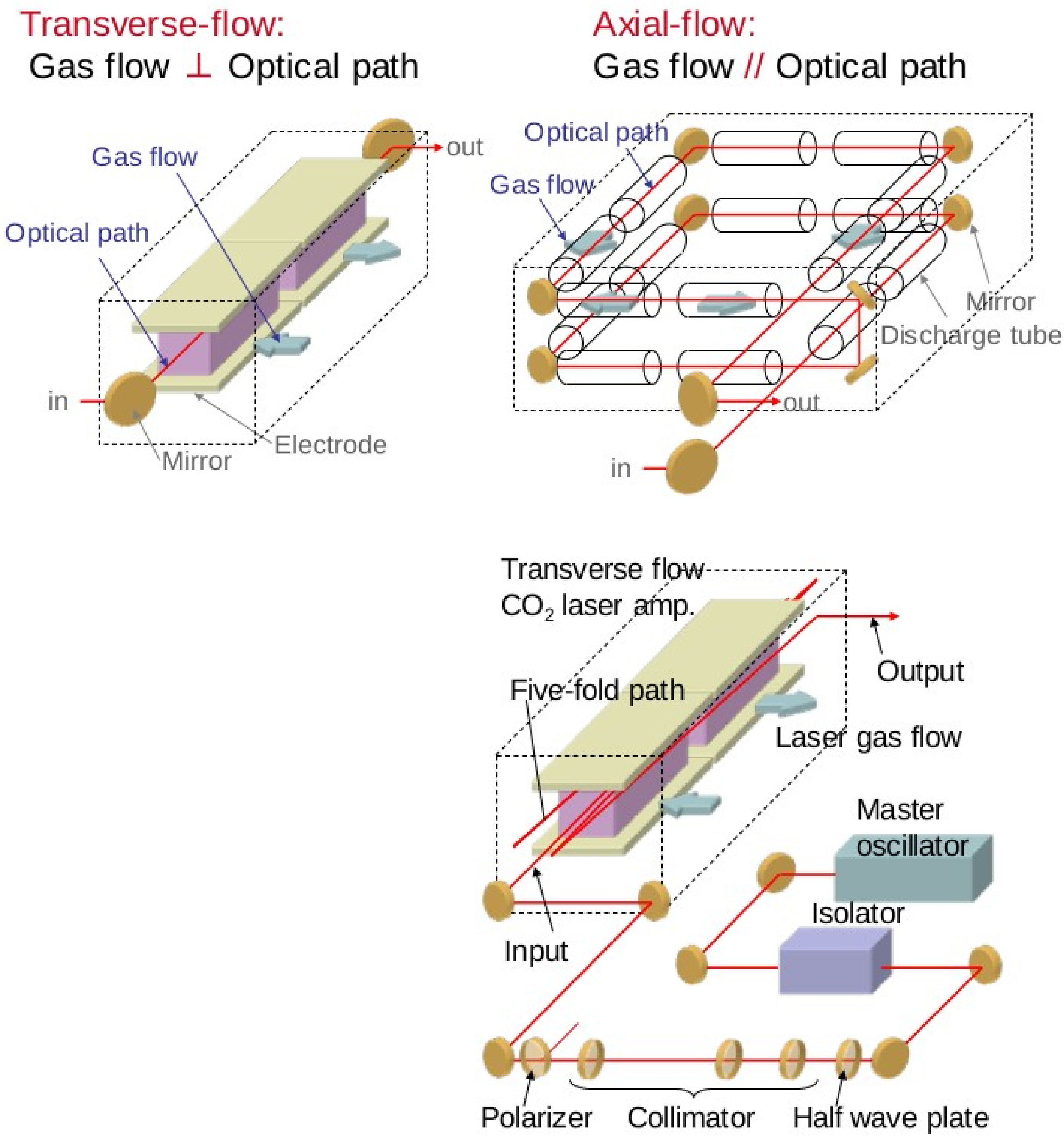
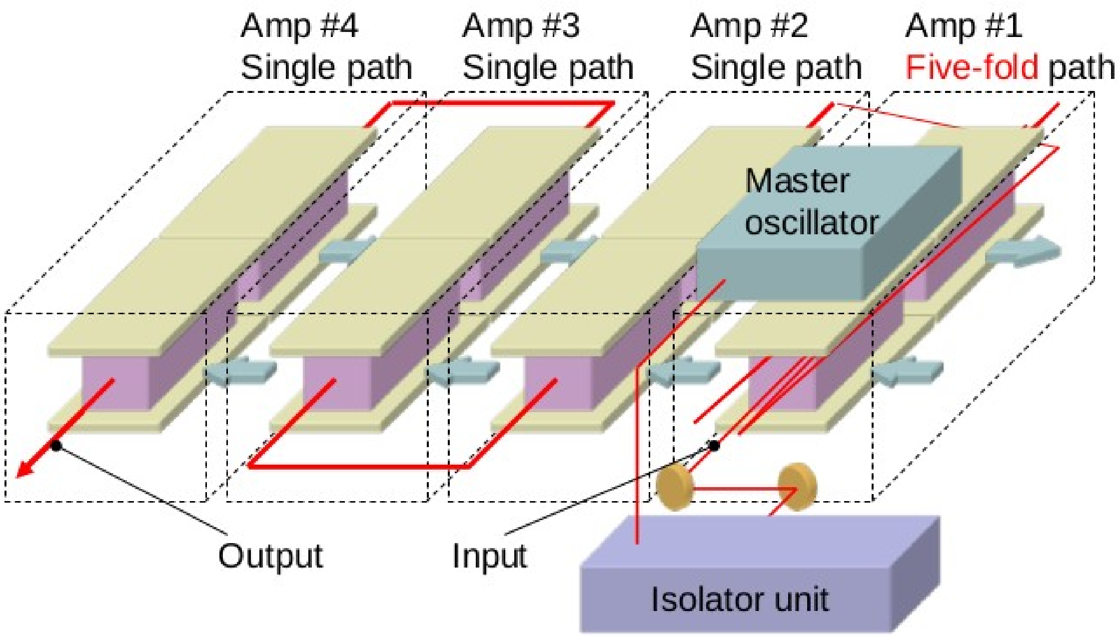
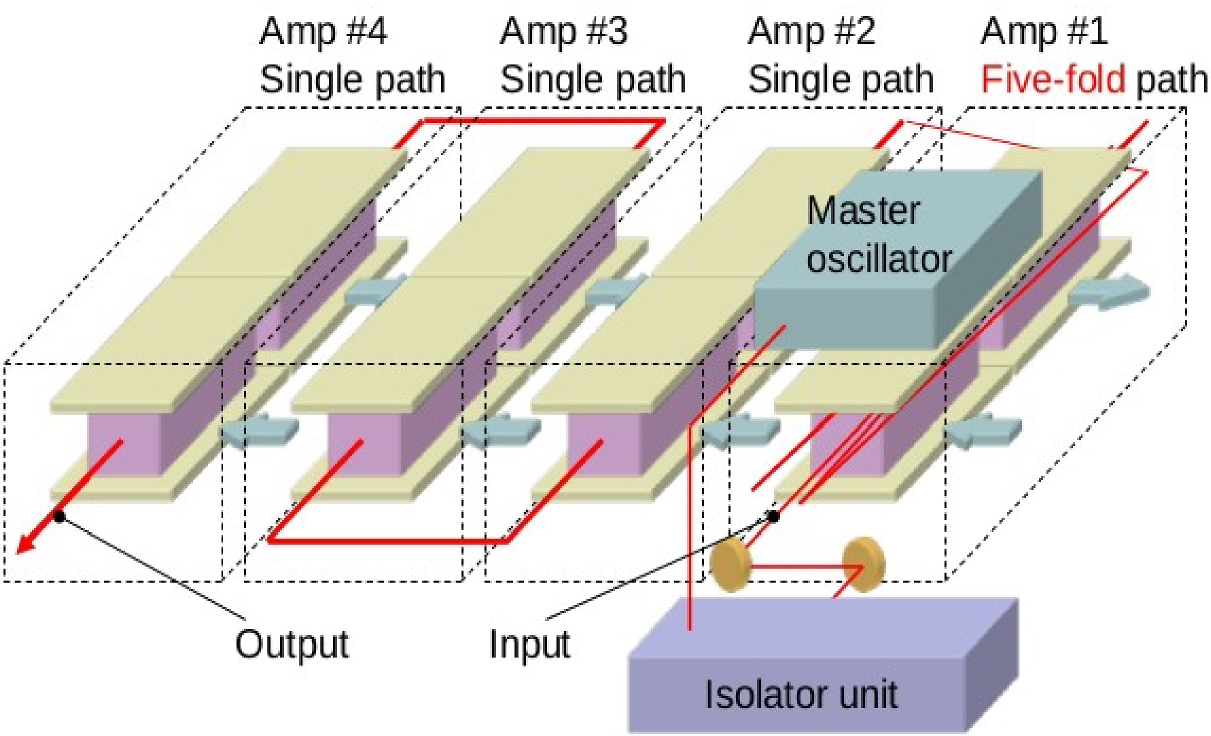


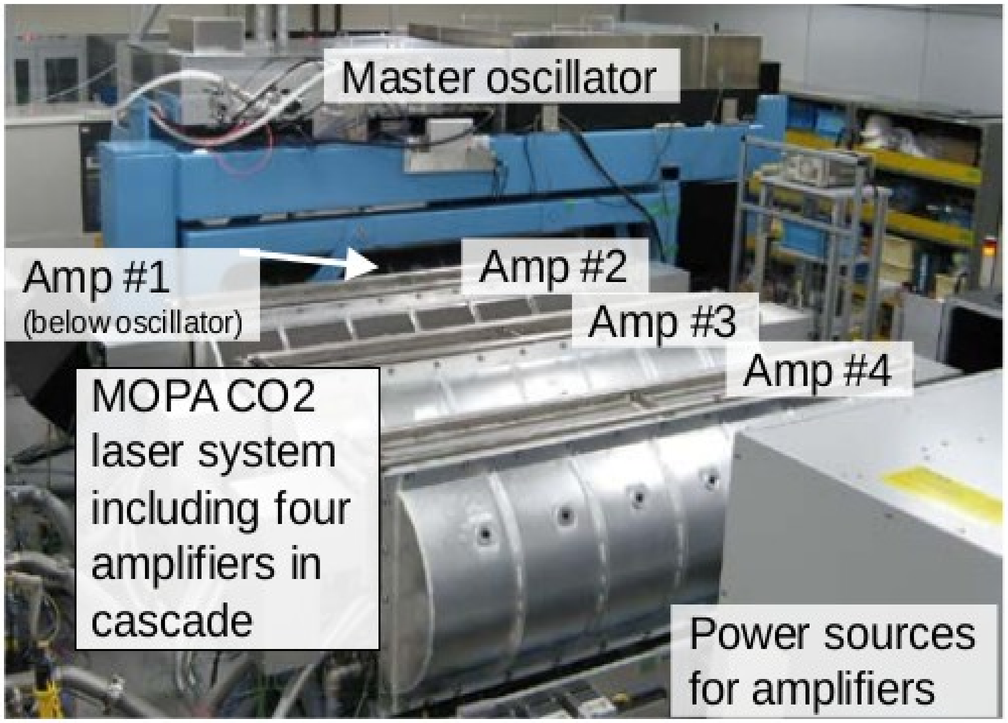
Figure 2. Configuration of the experimental setup.



. Schematic diagram of the prototype high-power pulsed CO_2 laser system.

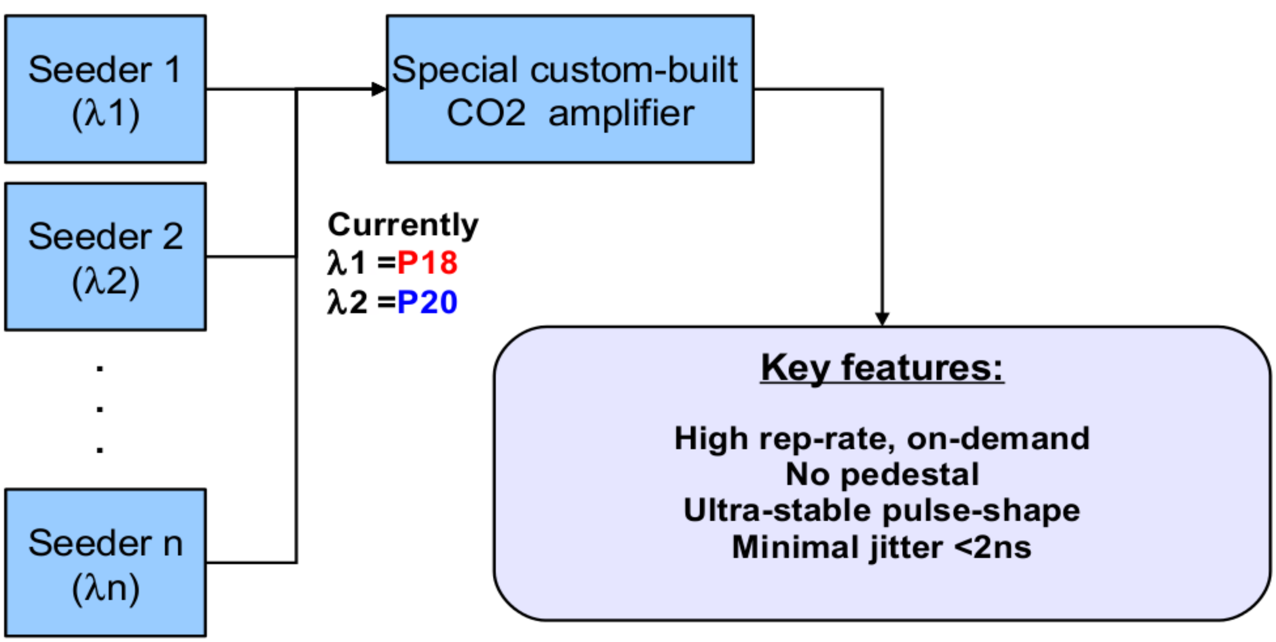

Amp #4
Single path
Amp #3
Single path
Amp #2
Single path
Amp #1
Five-fold path
Master
oscillator
Output
Input
Isolator unit

. Schematic diagram of the prototype high-power pulsed CO_2 laser system.

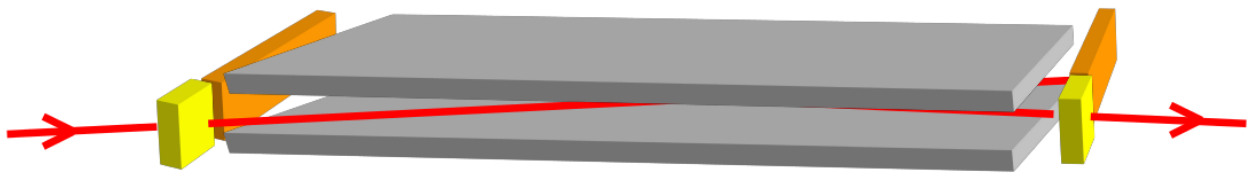


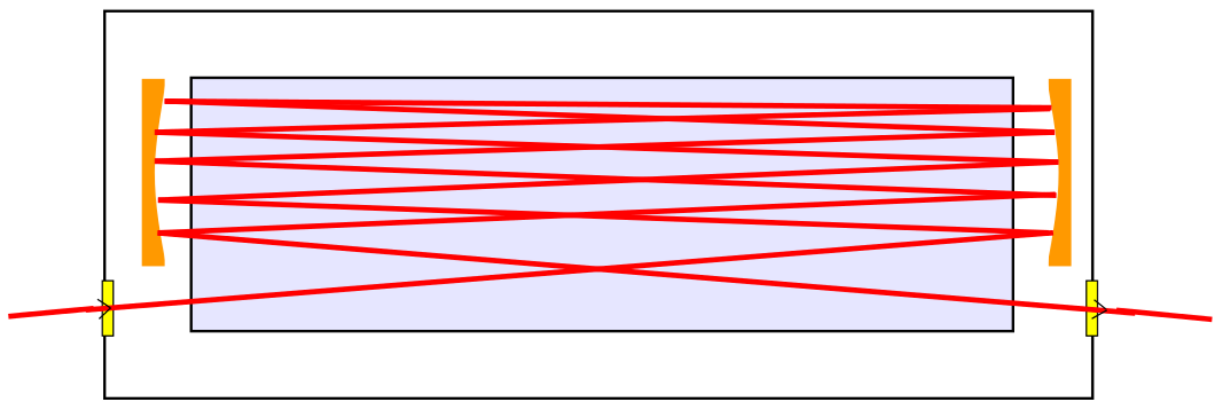
6. Picture of the prototype high-power pulsed CO_2 laser system.

Novel approach to multi-line ns pulse generation at 10.6 microns – amplification of QCL seed (2009)

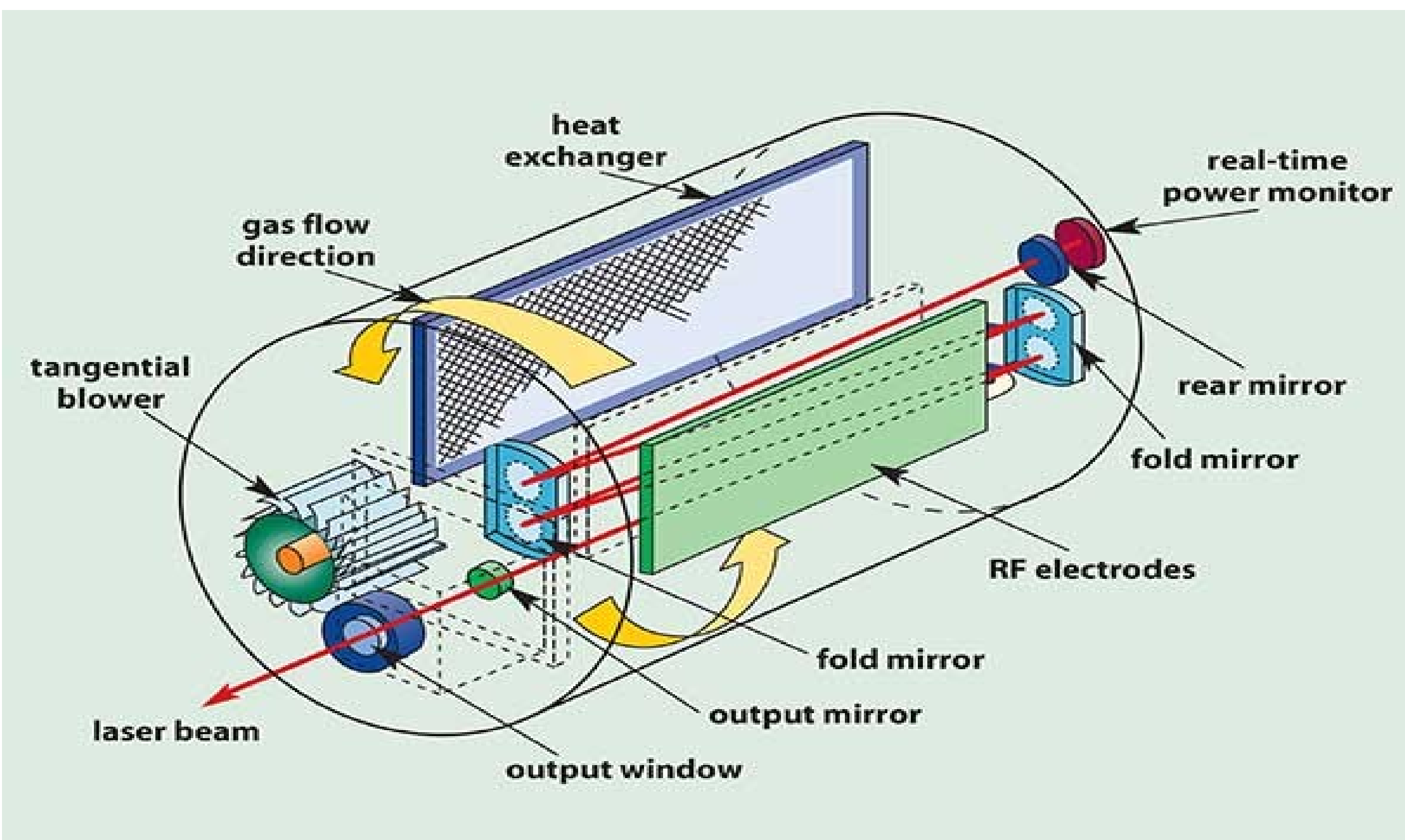


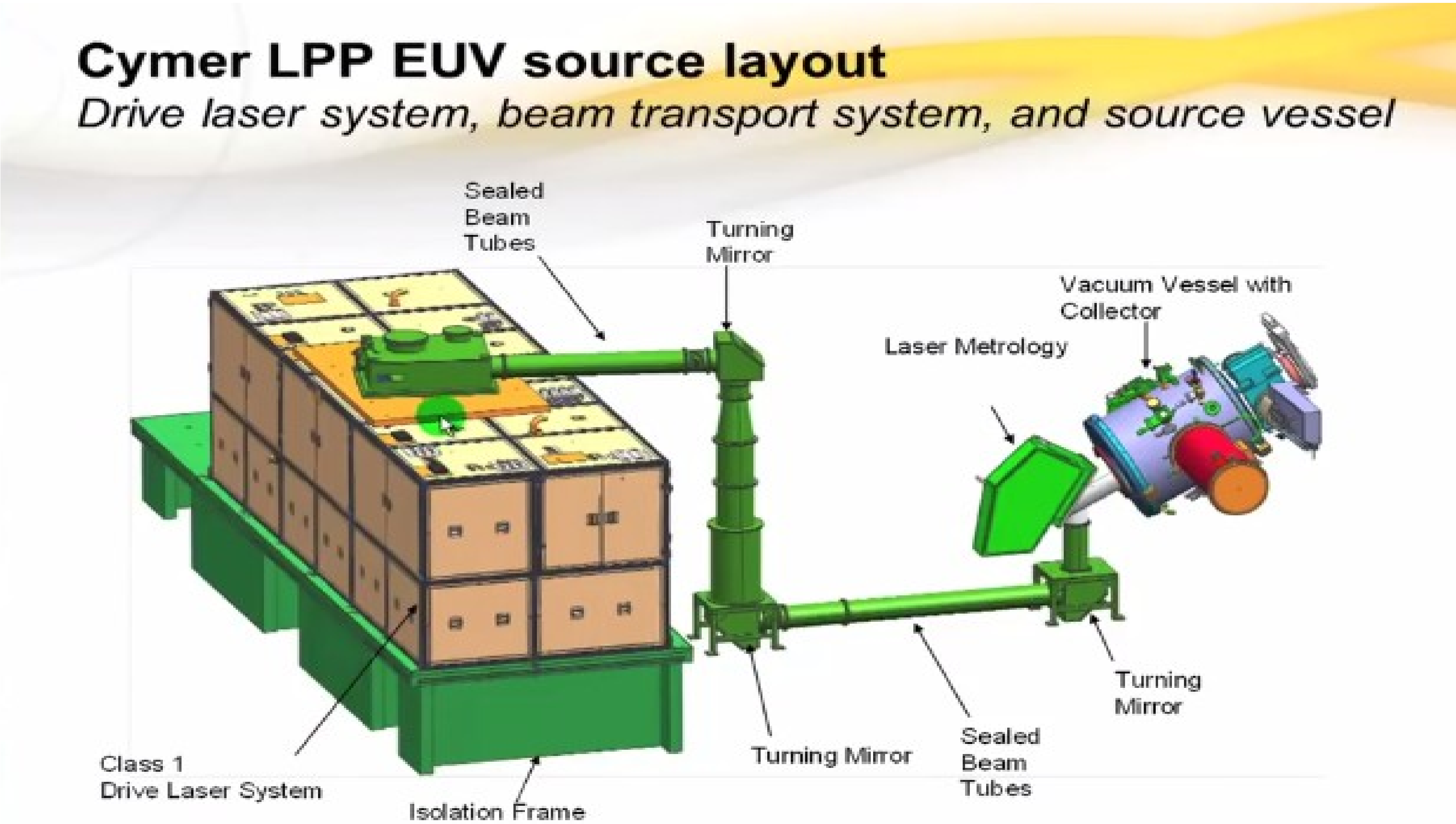
Slab-waveguide amplifier based on RF-discharge-excited diffusion-cooled CO_2 lasers - concept

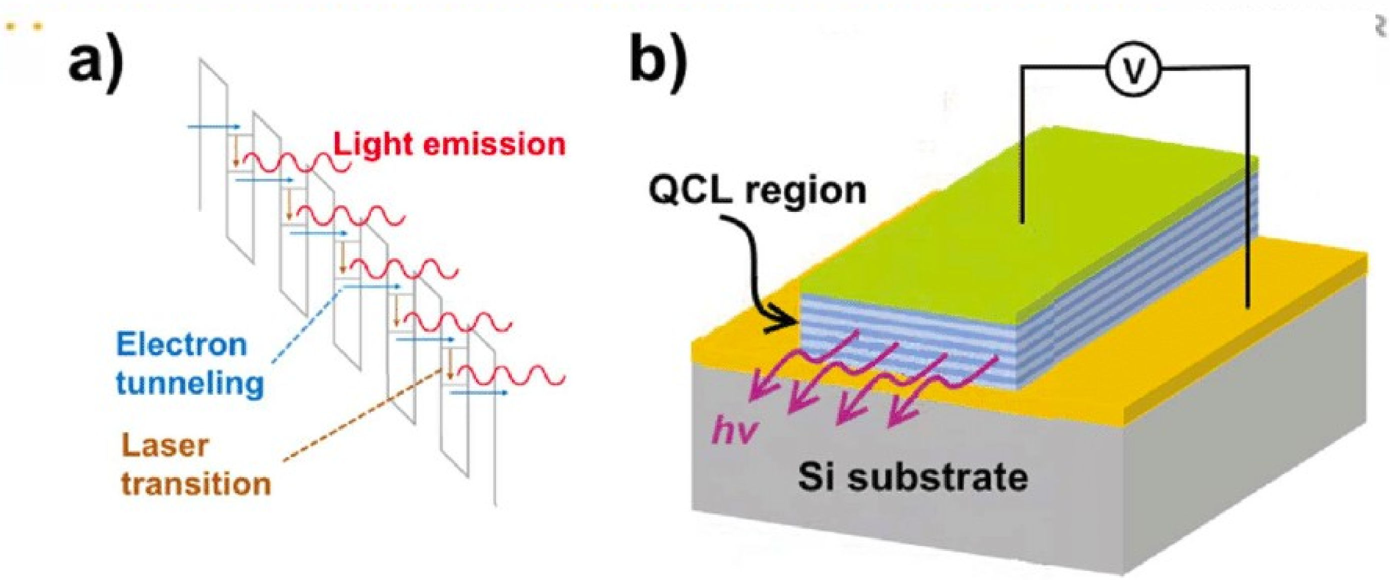




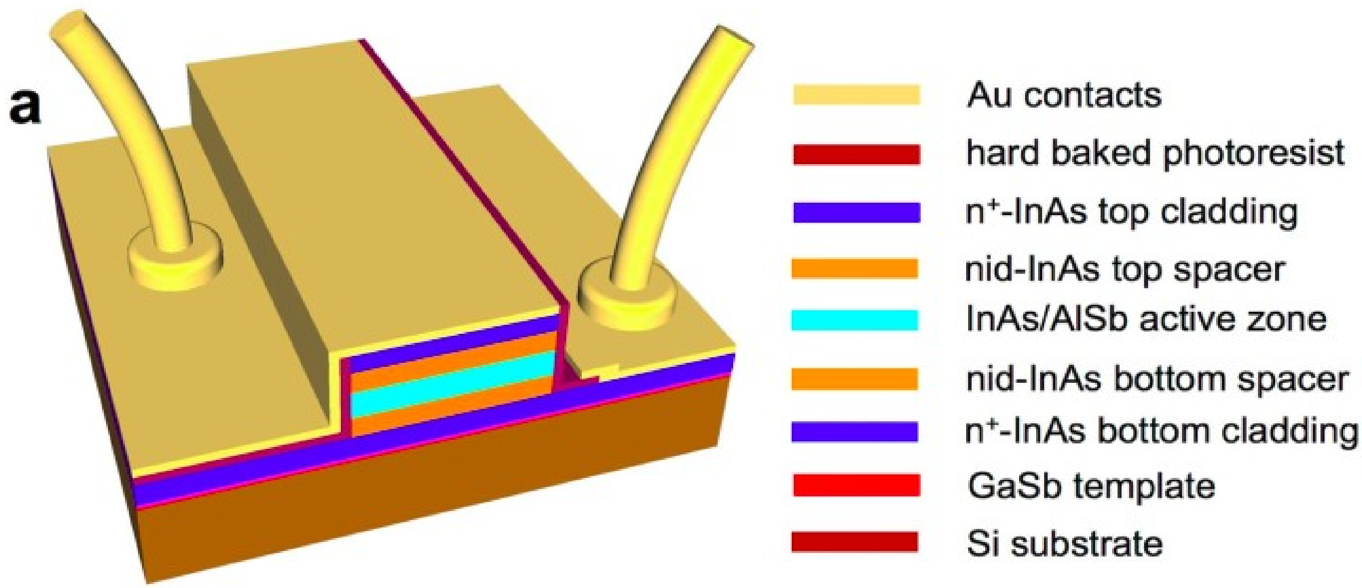
FTF Amplifier

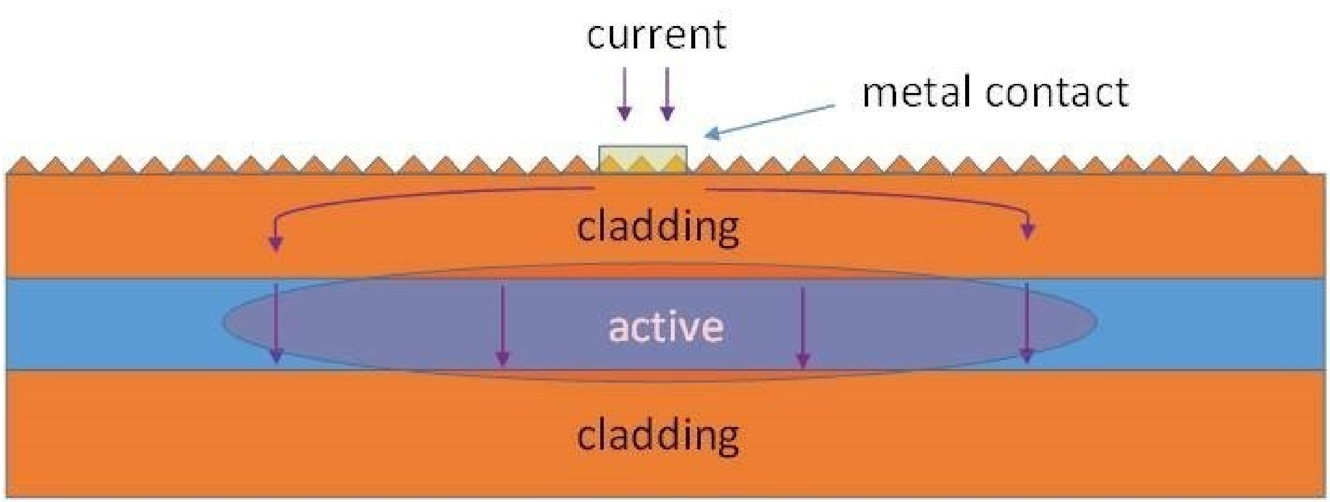






Quantum Cascade Laser





Pulse operation

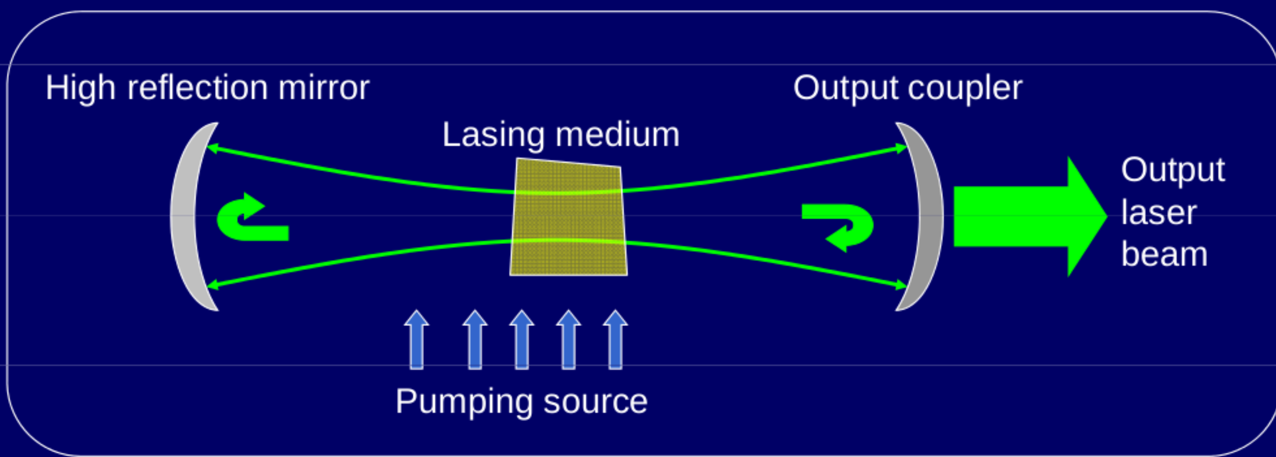
Q-switch: intense nanosecond pulses

Acousto-optic Q-switch

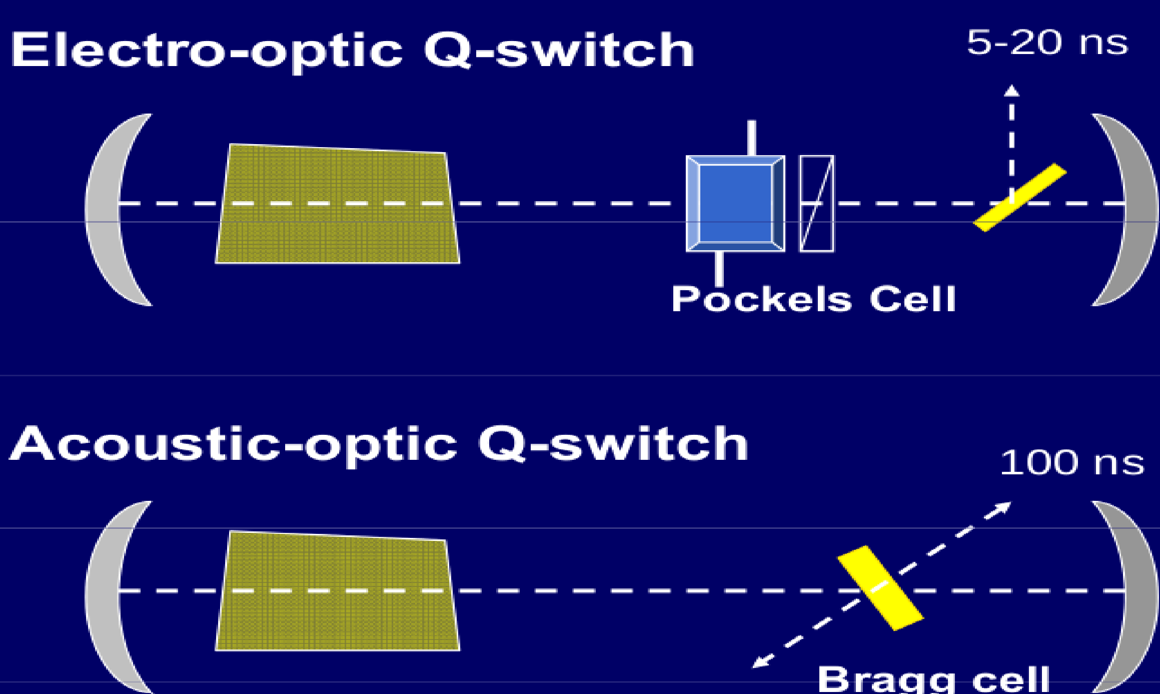
Electro-optic Q-switch

Mode-locking: femtosecond (10^{-15} s) or picosecond (10^{-12}s) pulses

Schematic of a Laser Cavity

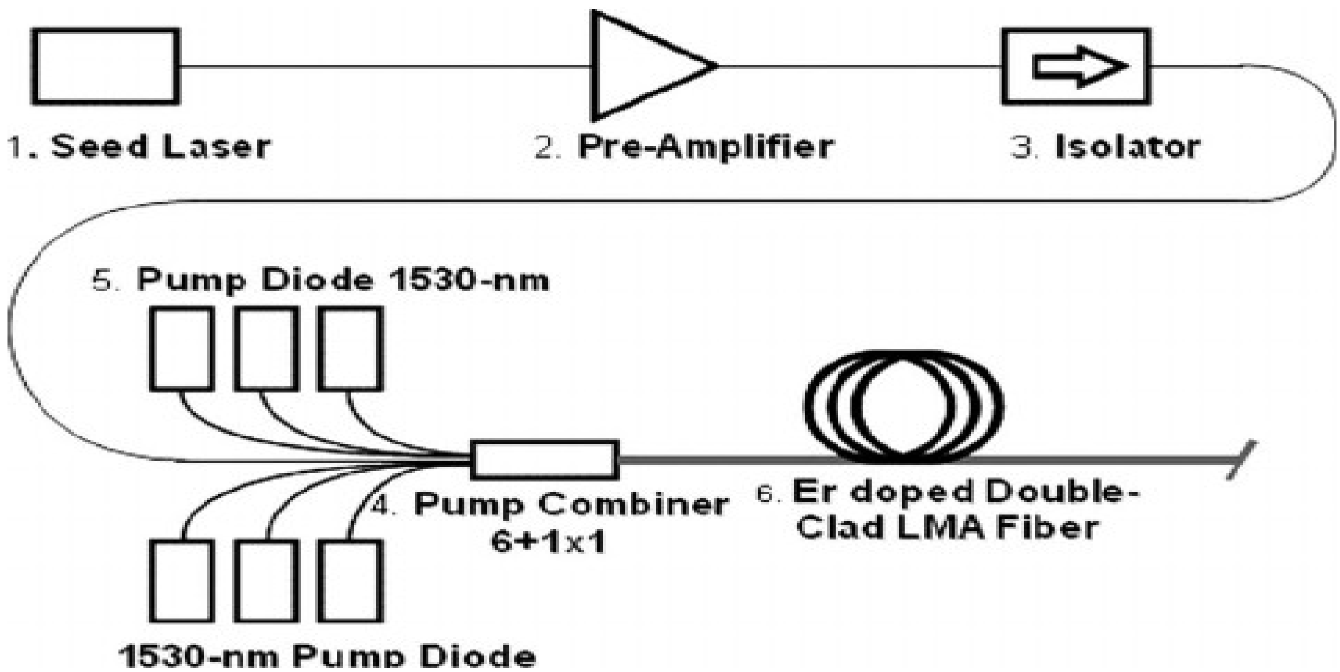


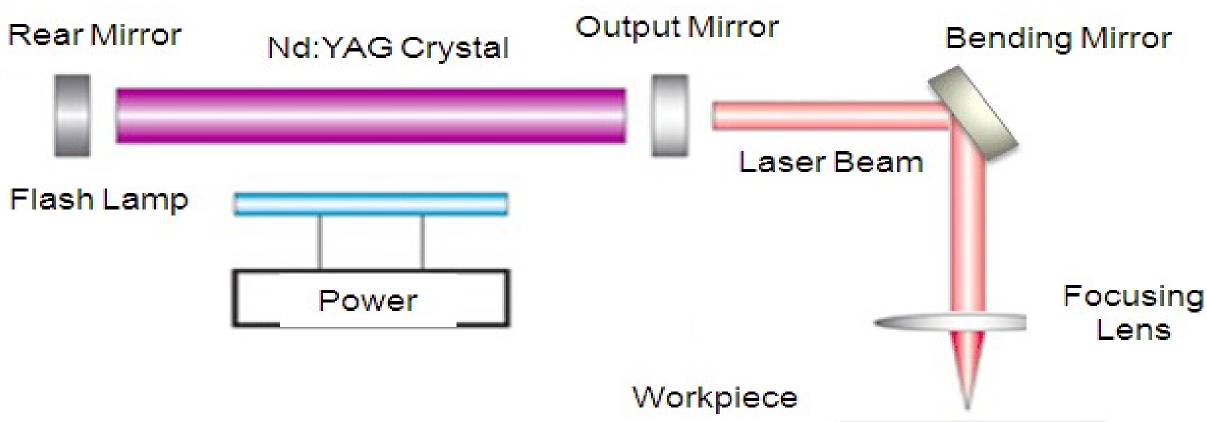
Q (quality)-Switch Operation

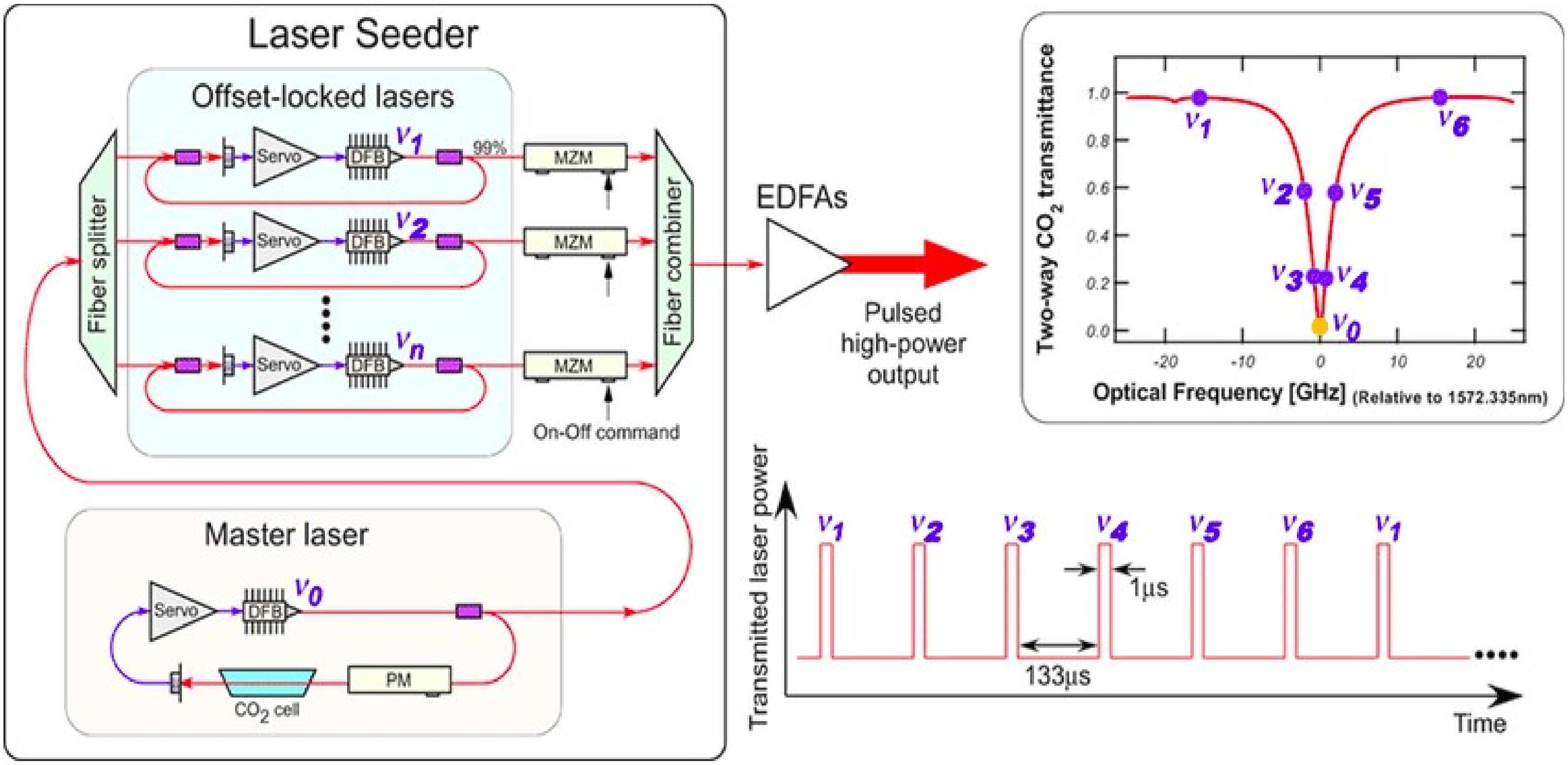


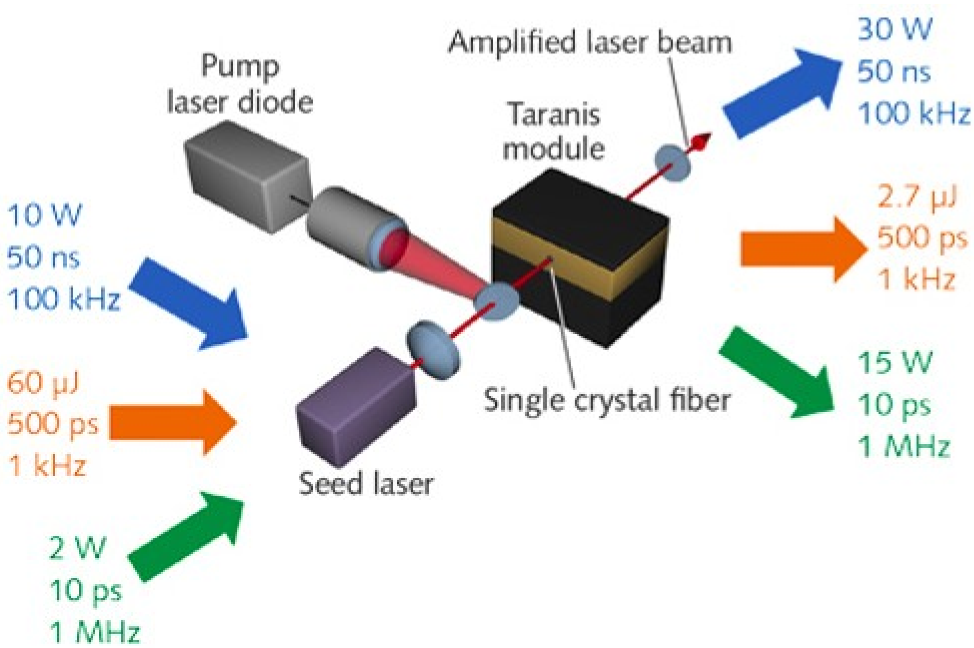
A Pockels cell based on KD*P, which can be used for Q switching of solid-state lasers.

A Pockels cell is a device consisting of an electro-optic crystal (with some electrodes attached to it) through which a light beam can propagate. The phase delay in the crystal (→ *Pockels effect*) can be modulated by applying a variable electric voltage. The Pockels cell thus acts as a *voltage-controlled waveplate*. Pockels cells are the basic components of electro-optic modulators, used e.g. for Q switching lasers.









A seed laser is a laser the output which is injected into some amplifier or another laser. This is done in, e.g., the following situations:

- A seed laser combined with an amplifier forms a *master oscillator power amplifier* configuration, used for generating an output with high power.

Injection seeding fiber lasers is a widely used mode selection technique which uses a seed laser to selectively reduce the laser's gain threshold at that a specific wavelength.

This results in the laser's output having the same spectral properties as the seed laser, therefore, improving its overall performance characteristics. While this method can be used with both CW and pulsed fiber lasers, it is used mainly for producing narrow linewidth pulsed fiber lasers.

In this case, a single frequency fiber laser seed laser is coupled into the fiber laser optical cavity and pulsed via a gain switching electronic driver board which can be triggered and timed to coincide with the q-switched laser's pulse. This causes the laser to lock onto the seed lasers exact wavelength due to the reduction in the laser's gain threshold at that specific wavelength.

Seed Laser

Available Sources

LDH Series

Picosecond Pulsed Diode Laser Heads

- Wavelengths between 375 nm and 1990 nm
- Pulse widths as short as 50 ps (FWHM) or CW operation
- Adjustable (average) power up to 20 mW
- Repetition rate from single shot to 80 MHz

FSL 500

Fast Switched Diode Laser

- Pulse width adjustable between 3 ns and 100 ns
- Repetition rate from single shot to 12 MHz
- User-defined signal patterns via external triggering
- Wavelengths from 375 nm to 1550 nm, power levels up to 40 mW

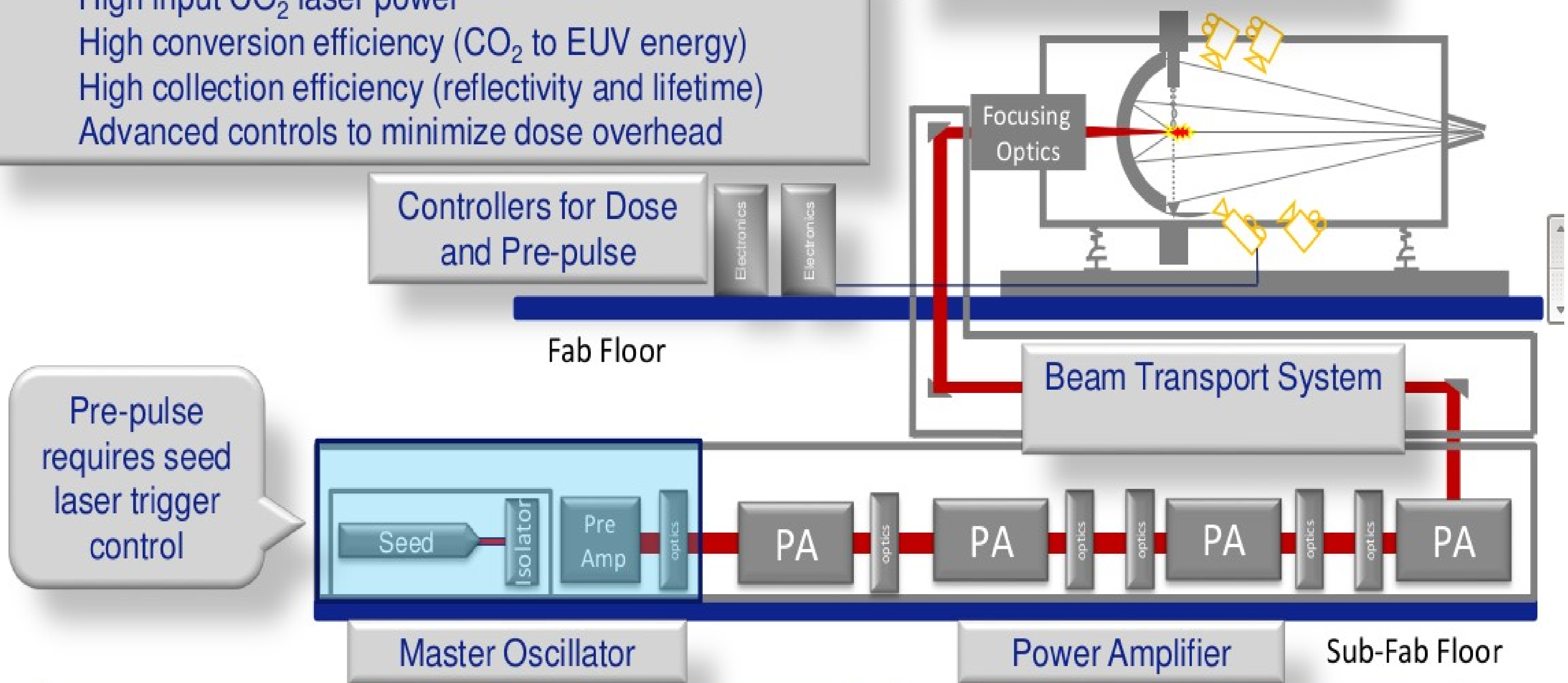
PPL 400

Diode Laser with Programmable Pulse Shape

- Center wavelength: 1062 nm
- Pulse width between 1 ns and 330 ns with programmable pulse shape
- Repetition rate up to 1 MHz
- Various operation modes: bursts, sequences, burst sequences

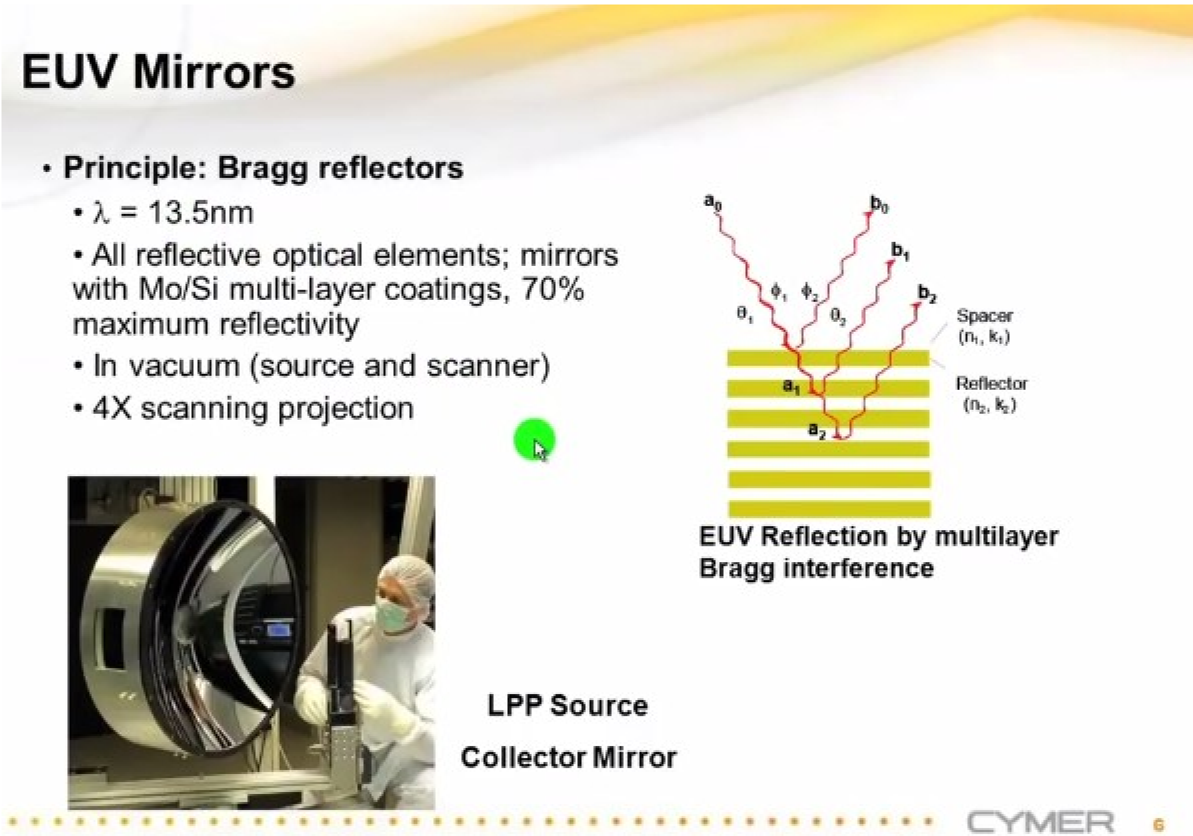
LPP: Master Oscillator Power Amplifier (MOPA)
Pre-Pulse Source Architecture

- Key factors for high source power are:
  - High input CO_2 laser power
  - High conversion efficiency (CO_2 to EUV energy)
  - High collection efficiency (reflectivity and lifetime)
  - Advanced controls to minimize dose overhead



EUV power (source/scanner interface, [W]) ∝ CO_2 power [W] * Conversion Efficiency [%] * 1 – Dose Overhead [%]

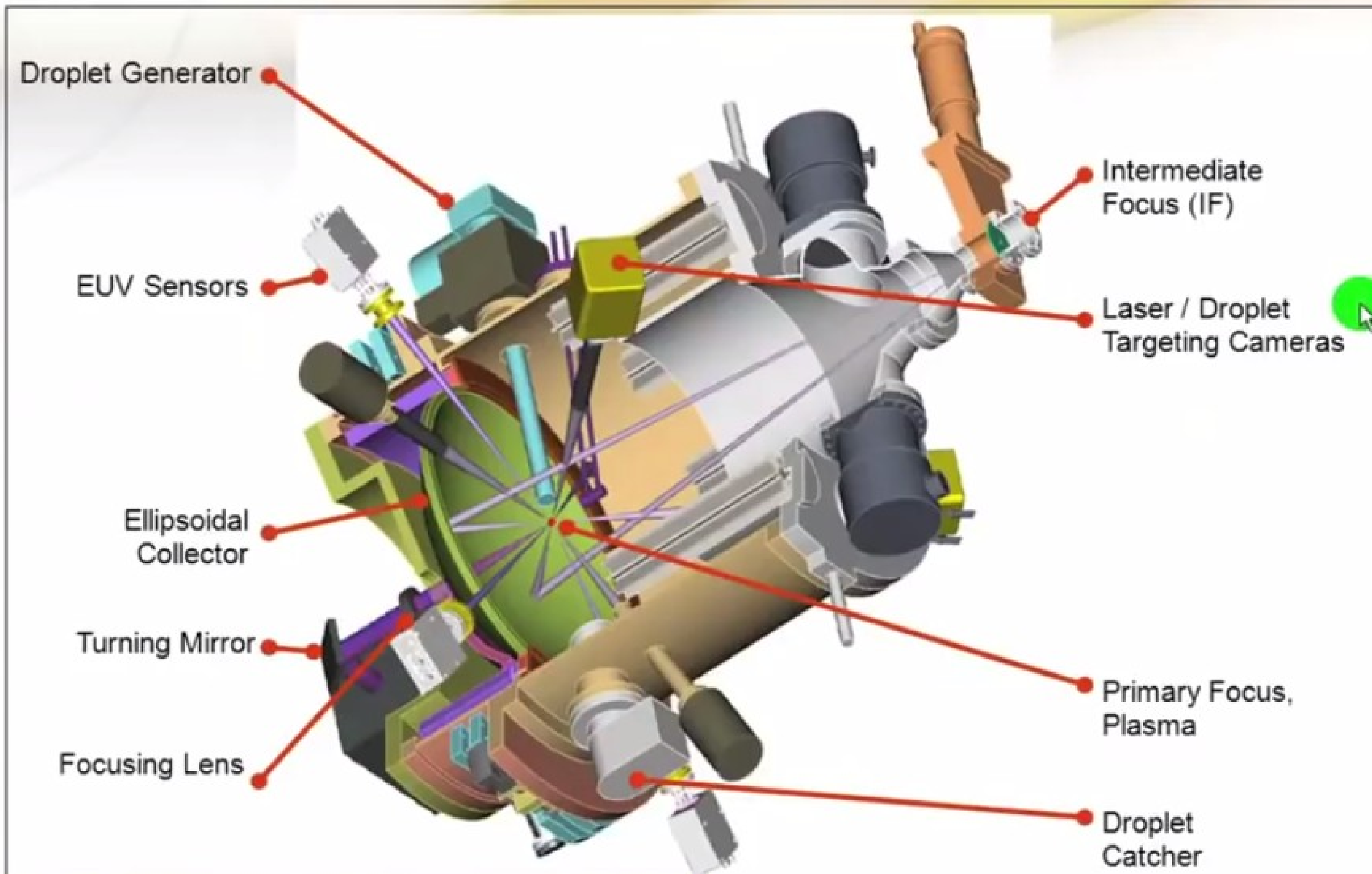
Collector Mirror
collect EUV light emitted by the Tin plasma in the Vaccum Vessel and directed the light to IF section of the stepper/scanner



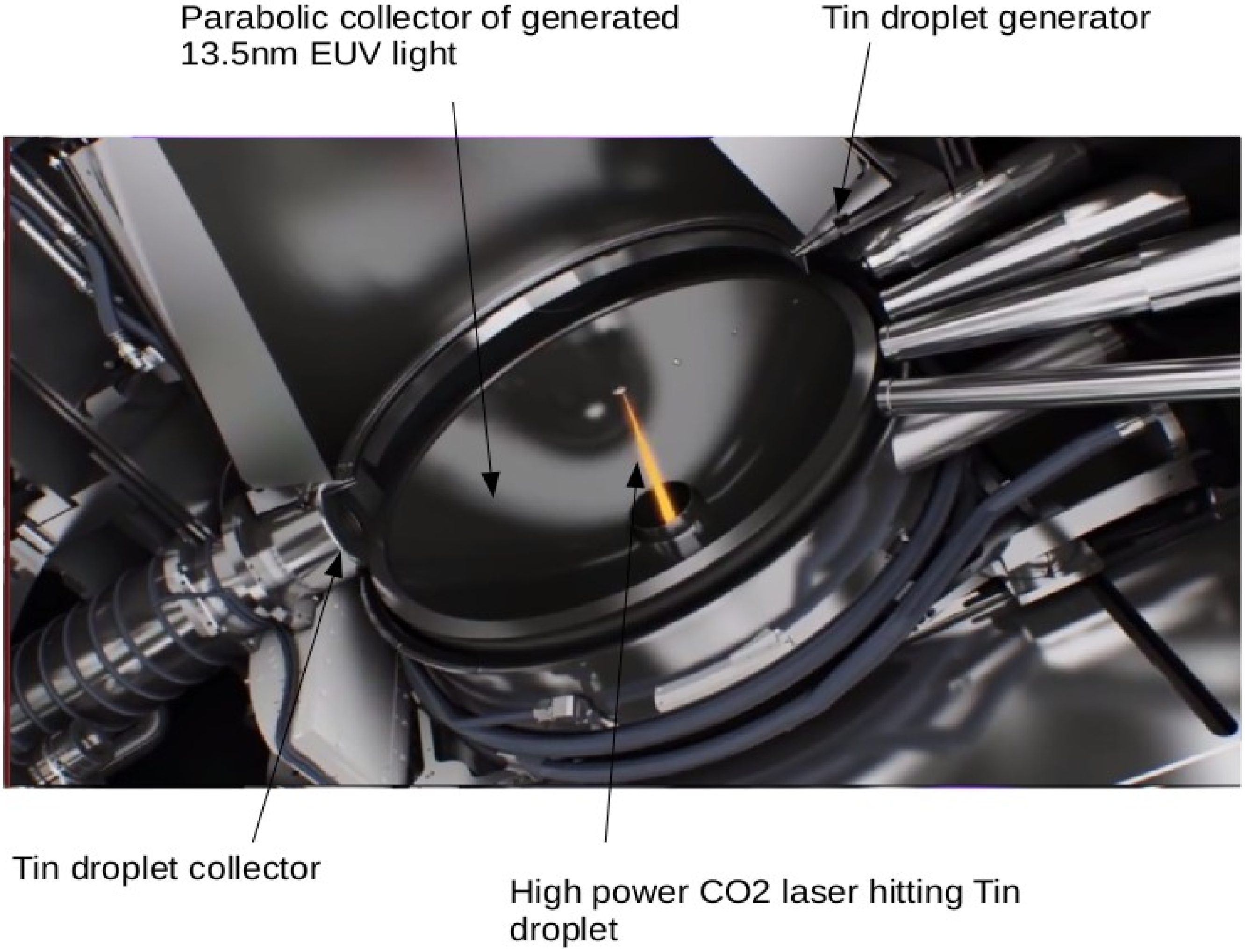
Manufacturing processes

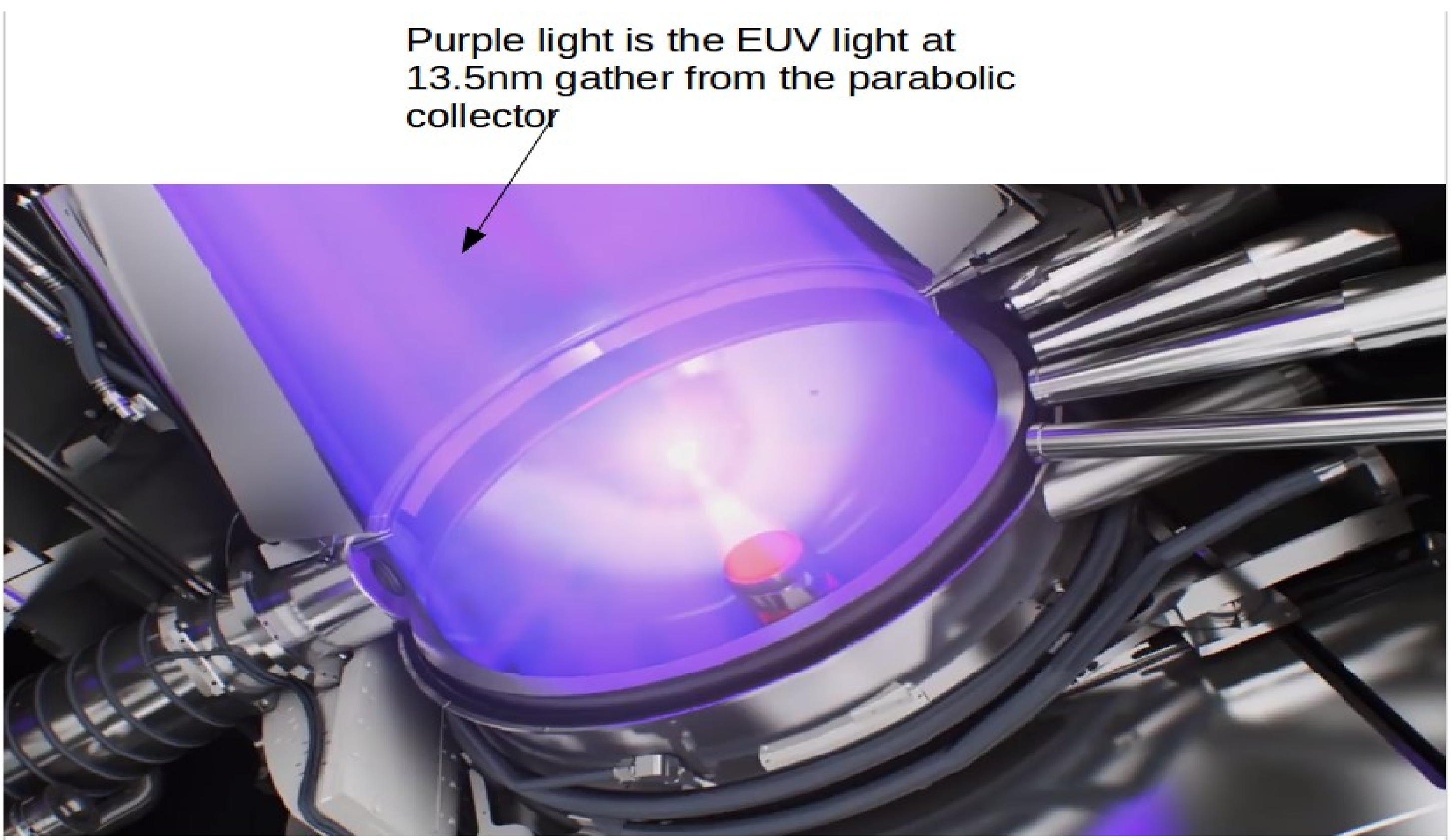
Blank machining
Shaping the figure
Coarse polishing
Super polishing
MLM coating
Reflectivity measurement

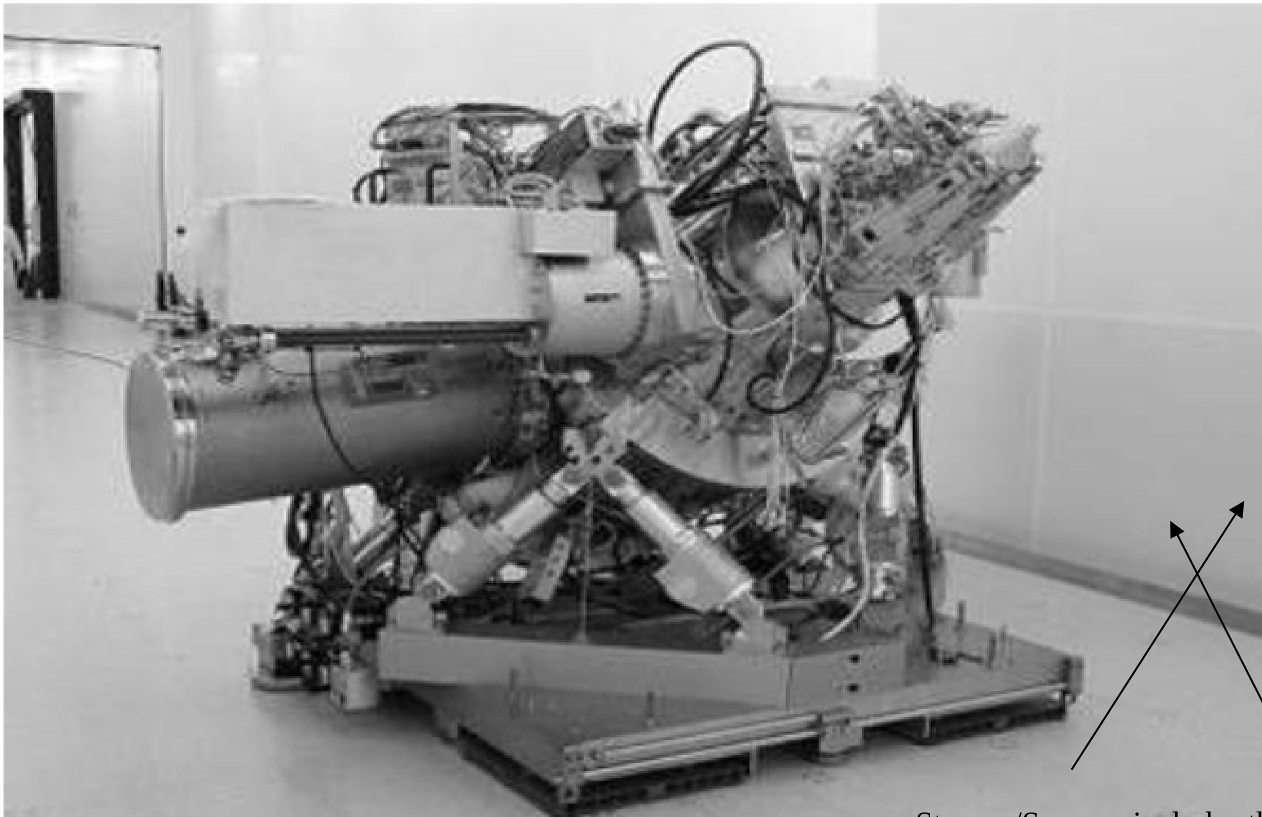
Cymer LPP EUV Source Vessel Architecture



Target Power:
100W for process development tools
250W for high-volume manufacturing


Parabolic collector of generated
13.5nm EUV light
Tin droplet generator
Tin droplet collector
High power CO2 laser hitting Tin
droplet


Purple light is the EUV light at
13.5nm gather from the parabolic
collector

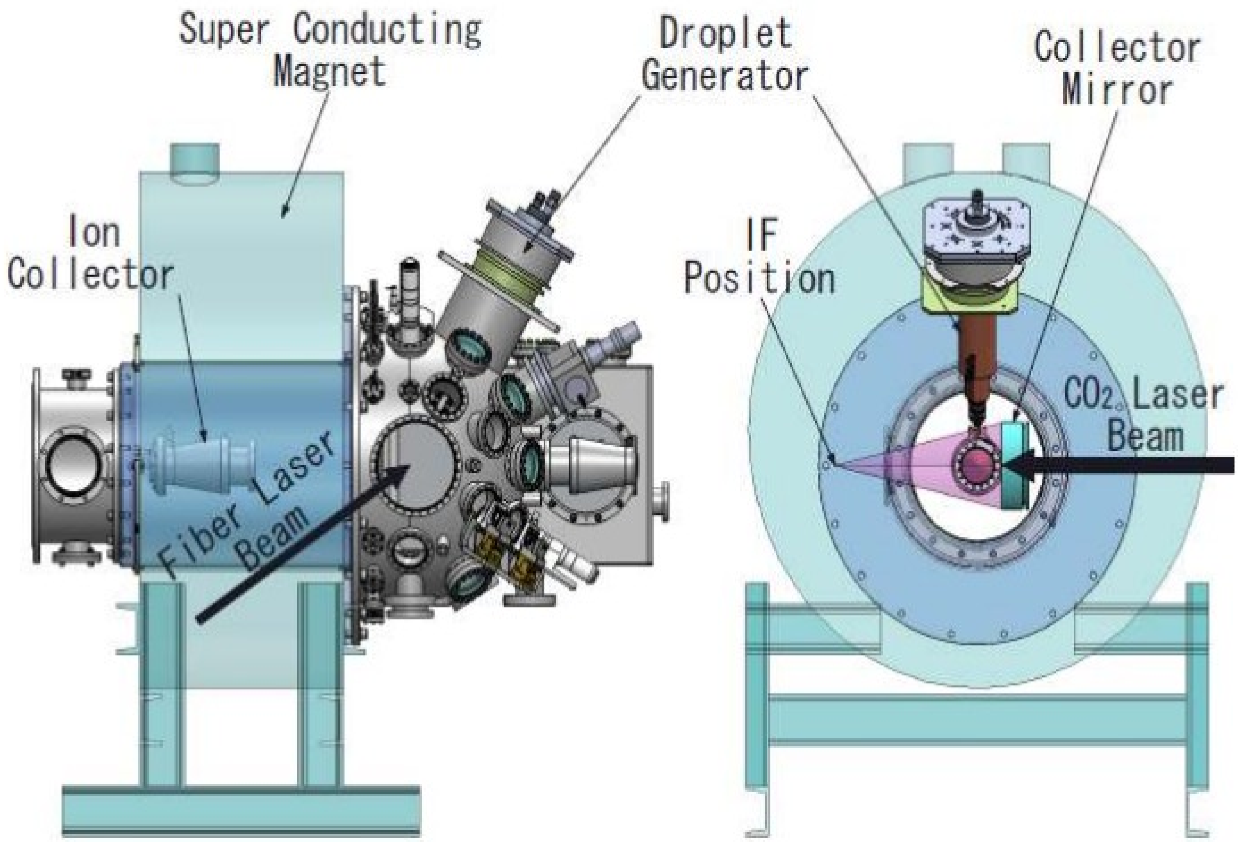


HVM I LPP Source Vessel moving into the customer cleanroom.

Stepper/Scanner includes the Vaccum Source Vessel

The huge CO2 laser system is located at different area, in the sub fab. The Beam transport System transport the laser to the Vaccum Source Vessel.

HVM I LPP Source Vessel Integrated into the NXE 3100 Scanner.



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