Barometric Comparison Results from the 7105 GODL Station

Van Husson

NESC Meeting: June 7, 2023

Peraton

Introduction

- The NASA SLR network purchased a second barometer, a Vaisala PTU303, to be used as a traveling barometric standard
- The current legacy NASA SLR network is comprised of MOBLAS 4-8, TLRS-3 & -4. These systems all have the Paroscientific MET4 meteorological sensor that are mounted outdoors at the same height as the system reference point (i.e. the intersection of the optical axes)
- Our first comparison was conducted at MOBLAS-7 (Station 7105) located in Greenbelt, Maryland. Data was taken in parallel for 6 days every 15 minutes

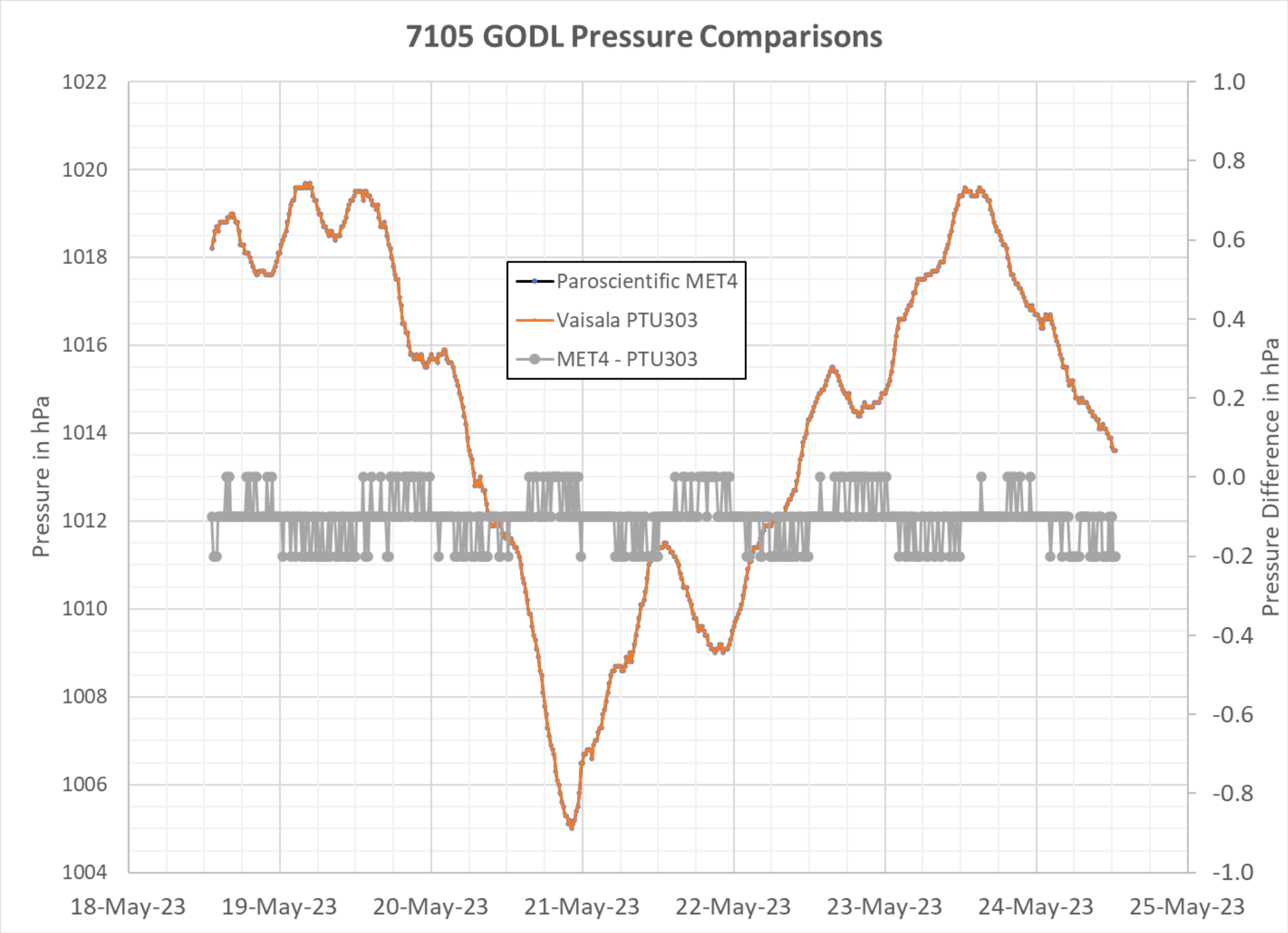
7105 GODL Meteorological Sensors

Vaisala PTU303

Paroscientific MET4

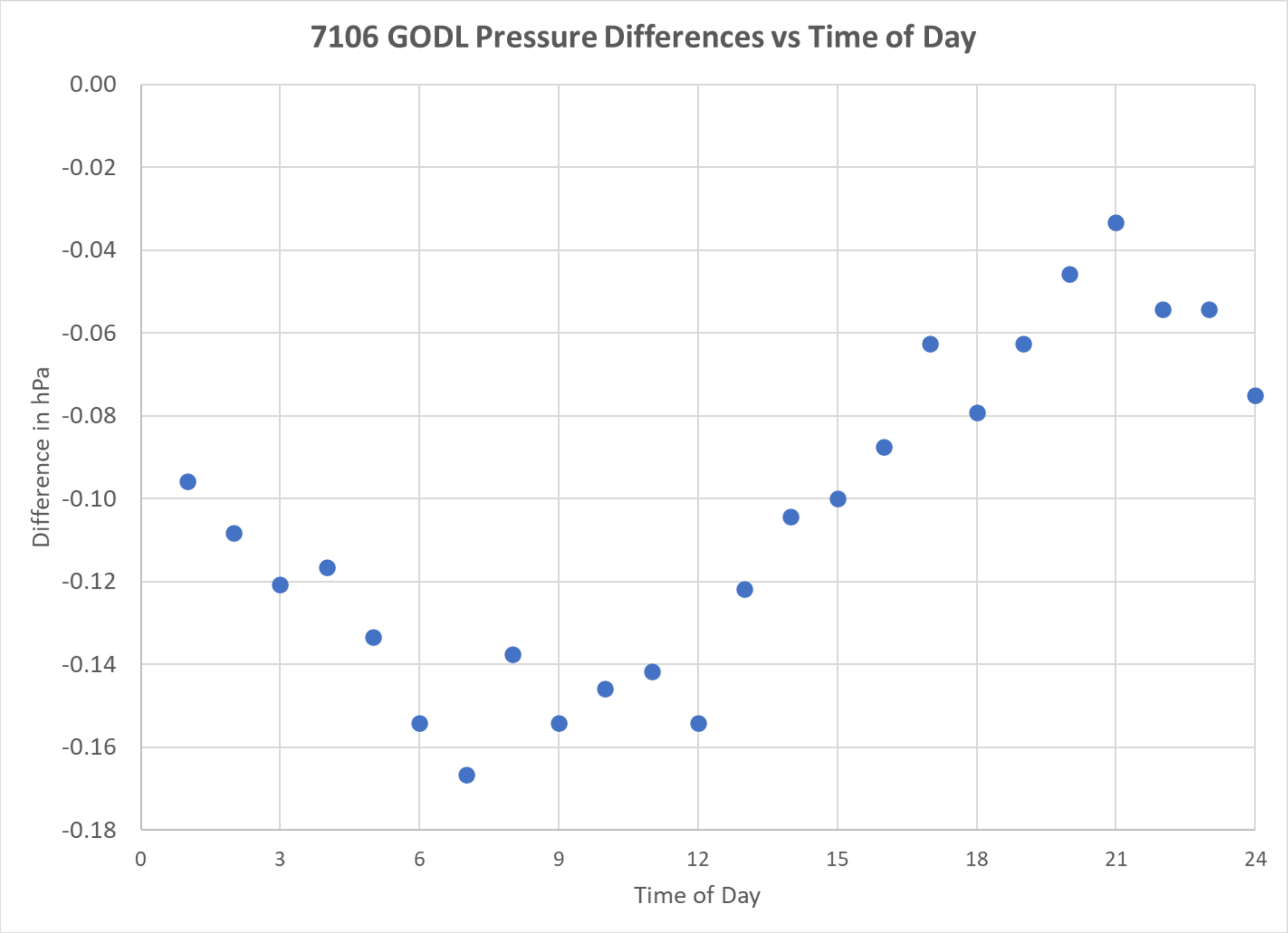
- There is a small height difference of 60 cm between the two sensors with the MET4 being higher
- The height difference can account for a 0.06 hPa difference in the pressures with the Vaisala PTU303 measuring a higher pressure

7105 GODL Barometric Comparisons



- ❑The peak-to-peak pressure differences were ±0.1 hPa with a mean offset of 0.10 hPa
- ❑The height difference can account for 0.06 of the 0.10 hPa difference
- ❑Therefore, the barometers agreed to 0.04 hPa

7105 GODL Barometric Comparisons



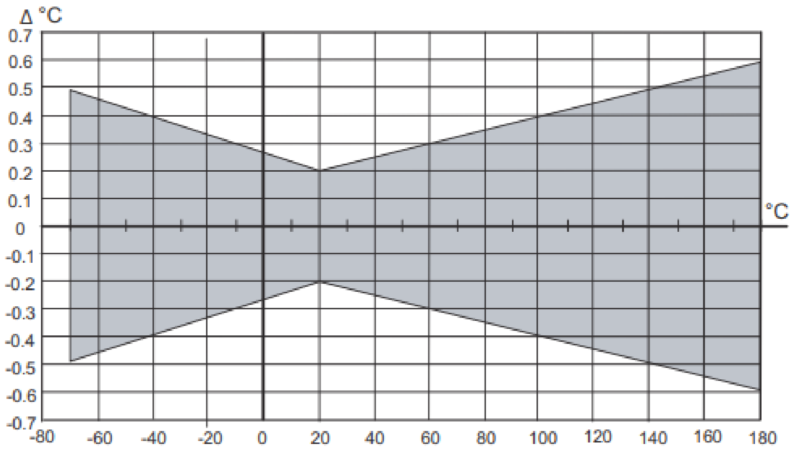
- **The differences are time of day dependent. Peak-to-peak variation is 0.14 hPa**
- **Temperature is also time of day dependent**

Vaisala PTU300 Specifications

Technical data

Measurement performance

Barometric pressure			
Pressure range		500 ... 1100 hPa	50 ... 1100 hPa
Accuracy	500 ... 1100 hPa	500 ... 1100 hPa	50 ... 1100 hPa
	Class A	Class B	
Linearity	±0.05 hPa	±0.10 hPa	±0.20 hPa
Hysteresis	±0.03 hPa	±0.03 hPa	±0.08 hPa
Repeatability	±0.03 hPa	±0.03 hPa	±0.08 hPa
Calibration unceratinty	±0.07 hPa	±0.15 hPa	±0.20 hPa
Accuracy at +20 °C / +68 °F	±0.10 hPa	±0.20 hPa	±0.30 hPa
Temperature dependence	±0.1 hPa	±0.1 hPa	±0.3 hPa
Total accuracy (-40 ... +60 °C / -40 ... +140 °F)	±0.15 hPa	±0.25 hPa	±0.45 hPa
Long-term stability/year	±0.1 hPa	±0.1 hPa	±0.2 hPa
Response time (100 % response):			
One sensor	2 s	1s	1 s
Pressure units	hPa, mbar, kPa, Pa, inHg, mmH20, mmHg, torr, psia		
Relative humidity			
Measurement range		0 ... 100 %RH	



Accuracy over temperature range

Operating environment

Operating temperature	-40 ... +60 °C (-40 ... +140 °F)
Operating temperature with optional display	0 ... +60 °C (+32 ... +140 °F)
Humidity range	Non-condensing
Measurement environment	For air, nitrogen, hydrogen, argon, helium, and oxygen [1)]

1) *Consult Vaisala if other chemicals are present. Consider safety regulations with flammable gases.*

- According to the spec sheet, the most accurate pressures are when the temperature is 20 degrees Celsius
- Temperature dependency is ±0.1 hPa

Conclusions

- The 1st comparison results were excellent with a mean pressure difference of 0.04 after factoring in the height difference
- Some barometers have temperature dependencies and why some ILRS stations have their barometric sensor inside where the temperature is controlled
- The Vaisala PTU303 will be sent to the other stations in the NASA SLR network

Traveling Calibration Barometer project status

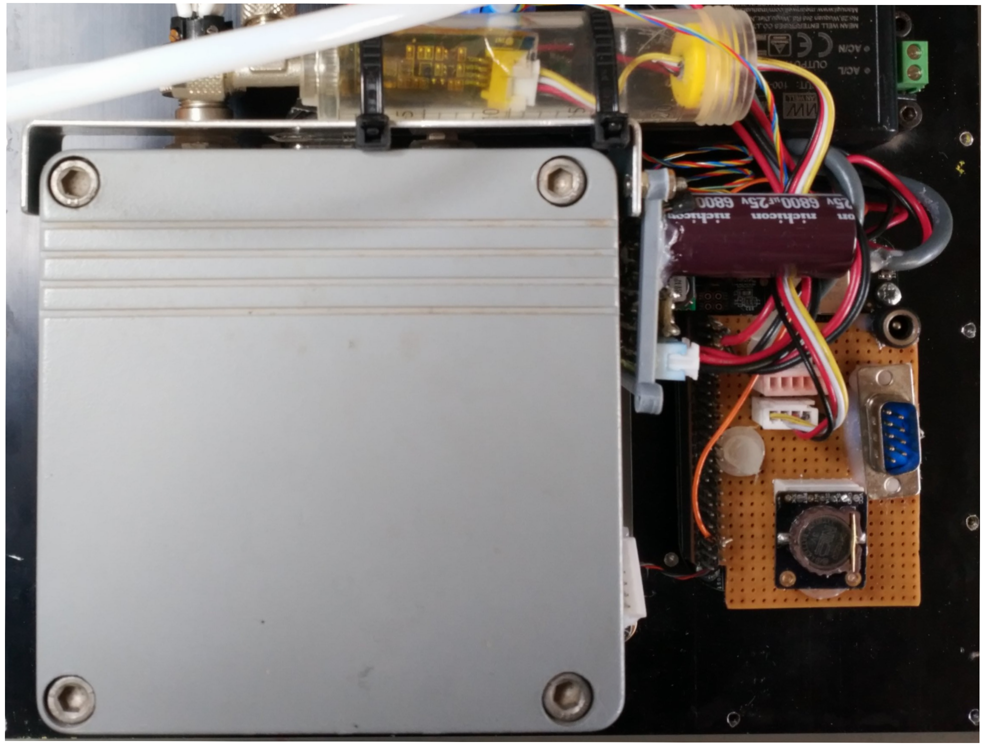
PI: Clément COURDE electronics: Nils RAYMOND mechanical: Julien SCARIOT

Sorry/Why this is taking so long

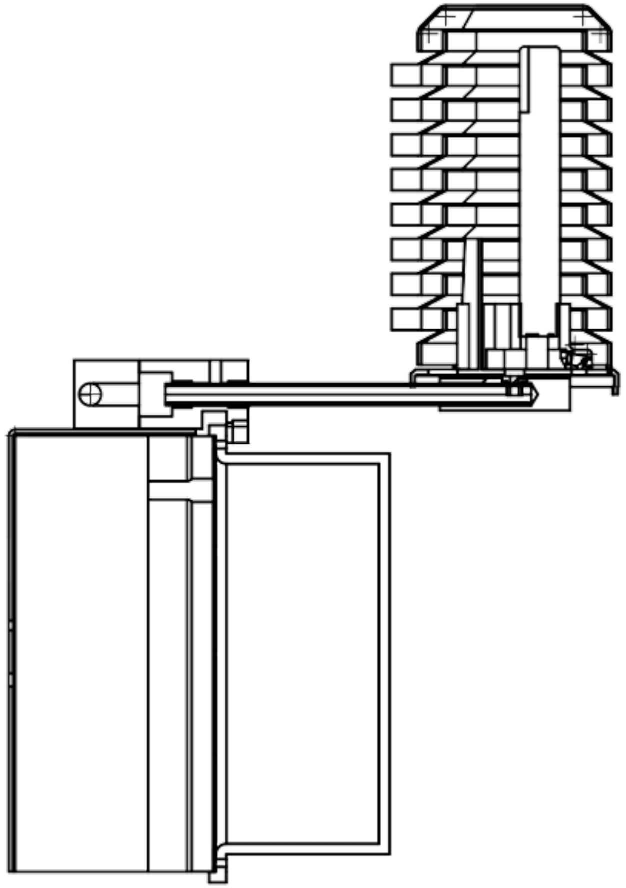
Sumarry

- Summarry
- Physical aspect
- stations.conf
- Scenario 1 : on surface, Line & ethernet
- Scenario 2 : on pole, PoE, LAN only
- Scenario 3 : cellular modem
- Scenario 4 : no ehternet, DC power
- You can now safely unplug your device
- Data upload architecture
- Project state : Done
- Project state : to do
- Questions about infrastructure
- Thank you

Physical aspect



Mechanical design



- foldable radiation shield, kept away from the radiator for accurate temperature measurement
- collapsible feet
- temperature & RH probe wires are fed through the pressure tube and share the same air tight connector
  - this connector can be kept plugged-in during shipping
- every component bolted to a thick radiator
- should be IP68 down to -40°C
  - the pressure tube does not communicate with the interior of the enclosure
- should be marine environment ready
  - most parts are CNC cut stainless steel
  - the radiator (the only aluminum part) is anodized
  - the enclosure will be made of 1 cm thick fiberglass and gel-coated, exactly like a sailboat

You can now safely unplug your device

protected 12V bus supplying the 5V DC/DC converter :

- capacitor for power storage
- inrush current limiter (for capacitor charge)
- reverse current protection
- input under voltage cutout (no output discharge)
- power good signal triggering interrupt
- over current protection
- short circuit protection

Results : - without circuit : **42 power failures triggered, 5 corrupted lines**
- with circuit : **1327 power failures triggered, 0 corrupted lines**

Ideal use scenario: line power, internet access

1) upload or email stations.conf containing NTP server address
2) unfold feet and install on table or ground
3) plug Ethernet (requires DHCP)
4) plug 110-230Vac
5) Done. you will receive a copy of all data every day

Power & networking requirements

Powering the device :

- line in (110 to 230Vac, 50-60 Hz)
- PoE (not yet implemented)
- 12Vdc (lead-acid & lithium battery compatible)

expect around 3W of consumption

Networking requirement

- network connection optional but NTP server highly recommended
- Ethernet only (no WiFi)
- DHCP auto-configuration (no static IP)
- fully autonomous if connected to the Internet
- intermittent connection acceptable
- can work with dynamic IP and restrictive firewall (Ethernet cellular modem compatible)

Data upload architecture

On device :

- when powered on, initialize sensors, try DHCP auto-configuration
- if network is available
  - retrieve emails
  - read stations.conf
  - (send LAN address?)
  - do NTP update
- start measurement, appending data to the latest file created
- just before midnight, if network is available,
  - create a new data file to be used for the next measurement
  - send email with previous data file
- whenever USB thumb-drive is plugged in:
  - copy all available data to it

On server :

- every night:
  - retrieve emails
  - upload data and stations.conf to EDC servers using SSH
  - save a copy of all data and stations.conf

Project state : Done

- device side hardware :
  - power management PCB prototype done and tested (but fairly fragile)
  - level shifting/BBB interface PCB prototype done and tested (last year)
  - enclosure : prototype stage
- device software :
  - measurement scripts done and tested (last year)
  - data upload by email done, needs more edge case testing
  - services, systemD and such : done
  - USB thumb-drive auto filling : done, needs stations.conf retrieval capability
- server software
  - email retrieving and data upload script done, needs testing and modification for final implementation
- server hardware
  - To Be Defined

Project state : to do

- device hardware
  - proper PCBs
  - PoE integration & tests
  - final fiberglass box fabrication and integration
  - water ingress testing
  - RTC needs more testing (especially in cold conditions)
  - ideally, thermal tests
  - status LEDs integration (& software)

- device software
  - stations.conf email retrieval script
  - stations.conf USB retrieval script
  - more edge case testing (sensors unplug, bad network connection
  - , …)
- server
  - get final infrastructure/email (OCA or ILRS)
  - update scripts and config for this infrastructure
  - manage data backups and alert
- shipping crate hardware
  - foam packing (hot wire)
  - wooden crate
- manual and documentation

stations.conf ?

- common to every scenario, what you will have to upload or send by email :
  - column 1: start date time
  - column 2: end date time
  - column 3: ILRS station id
  - column 4: Alternative station id with 4.digits when no ILRS station id available
  - column 5: Longitude (optional)
  - column 6: Latitude (optional)
  - (column 7: location comment?) "laser room", "on telescope tube", outdoor, ...
  - (column 8?) : NTP server(s) address
  - (column 9?) : contact addresses
- example :

```
2021-11-15|2021-12-31|7845|None|None|None|laser room|192.134.16.106 ntp-
c.oca.eu|nils.raymond@oca.eu clement.courde@oca.eu
```

Questions about infrastructure

- Is everyone using DHCP configuration (no static address) ?
- are most stations OK with device network access ?
- who hosts the server ?
  - OCA?
  - EDC?
- who's email account ?
  - account name ?
    - pressureBeagle
    - weatherBeagle
    - tmd.ilrs
    - TraCaB? (traveling calibration barometer)
- data format?
- local weather data upload/format?
  - save data at the minute

Thank you

- nils.raymond@oca.eu : email me your stations.conf to receive data
- sample :

timestamp	DPS310: pres.	temp.	vaisala: press	temp.	% RH
1685922720	883.2447	23.04	874.7518	20.00	49.55
1685922780	883.2452	23.04	874.7573	19.99	49.52
1685922840	883.2438	23.03	874.7628	20.01	49.57
1685922900	883.2436	23.04	874.7635	20.00	49.57
1685922960	883.2461	23.05	874.7485	19.99	49.59
1685923020	883.2438	23.04	874.7521	20.00	49.56
1685923080	883.2404	23.05	874.7264	20.00	49.59
1685923140	883.2370	23.04	874.7506	20.00	49.55

Ultrafast lasers for satellite ranging applications

Antoine Courjaud

Pessac 8 June 2023

Amplitude

01

Amplitude Laser Group

Leading Manufacturer of Ultrafast Lasers

Amplitude at a glance

Innovative & visionary company, created in 2001

Expert manufacturer in ultrafast laser technology

…10+ offices and production plants around the world.

400 +
employees worldwide

3 000
M² of production area

4 000 +
lasers in the field

Amplitude Laser Group Headquarters, near Bordeaux, France

Global company with a global reach

+400 employees working with the same passion, and delivering the best solutions.

High Quality

State-of-the-art

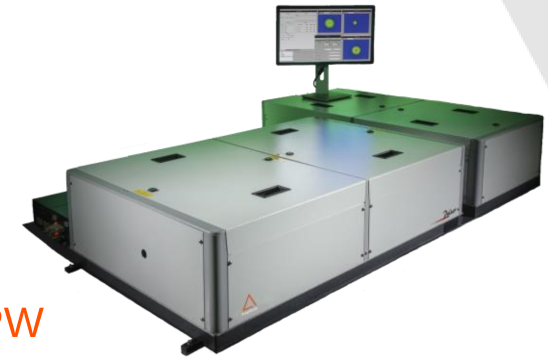
- Lifescience
- Protontherapy
- High Intensity and Energy Physics
- Spectroscopy and Imaging
- Instrumentation

Reliability

- Display
- Semiconductor
- Micro processing
- Ophthalmology
- Medical device manufacturing

Amplitude

What we can offer



The most complete and advanced Femtosecond & Nanosecond laser portfolio

High peak power: from TW to multi-PW

Ti:Sa-based solutions

> fs to ps, up to 10s J

High Energy

YAG/YLF based solutions

> ns, up to 100s J

High repetition rate

Yb-based solutions

> Hz to kHz, up to J, ps
> MHz, mJ, 100s fs

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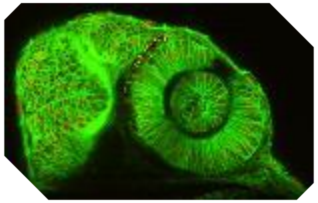
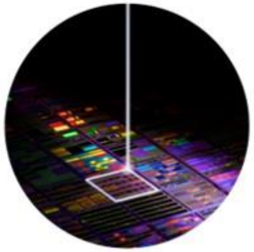
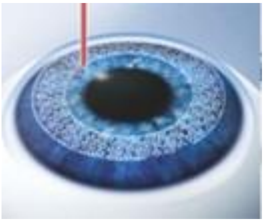
/ Applications

Observation

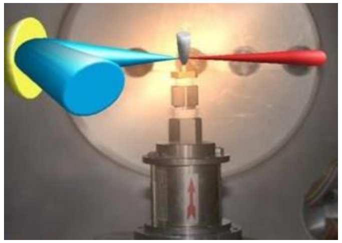


Interaction





Conversion



02

Laser processing

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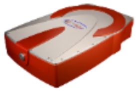
/ Industrial femtosecond laser history

1000x increase in average power in 20 years

2001	2009	2012	2016	2019	2021
1W	20W	10-50W	100-200W	500W	kW






Horizon 2020
European Union Funding
for Research & Innovation

Laser technologies:

solid state	fiber	fiber	fiber / solid state	fiber / solid state	fiber / solid state

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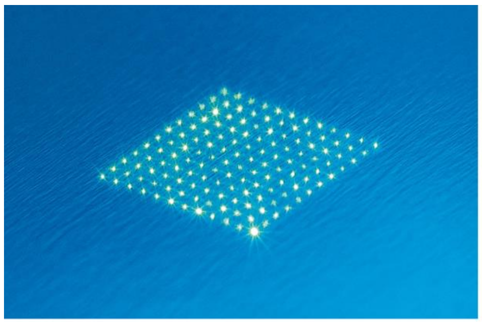
Multi Flex

Making Ultrafast Lasers Faster

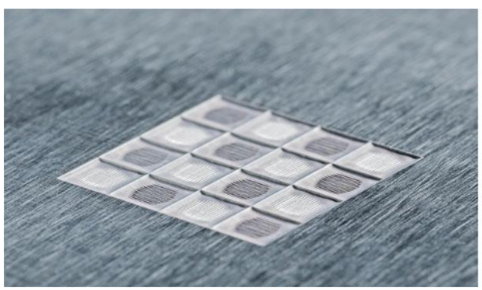
https://multiflex-project.eu/

PHOTONICS[21]

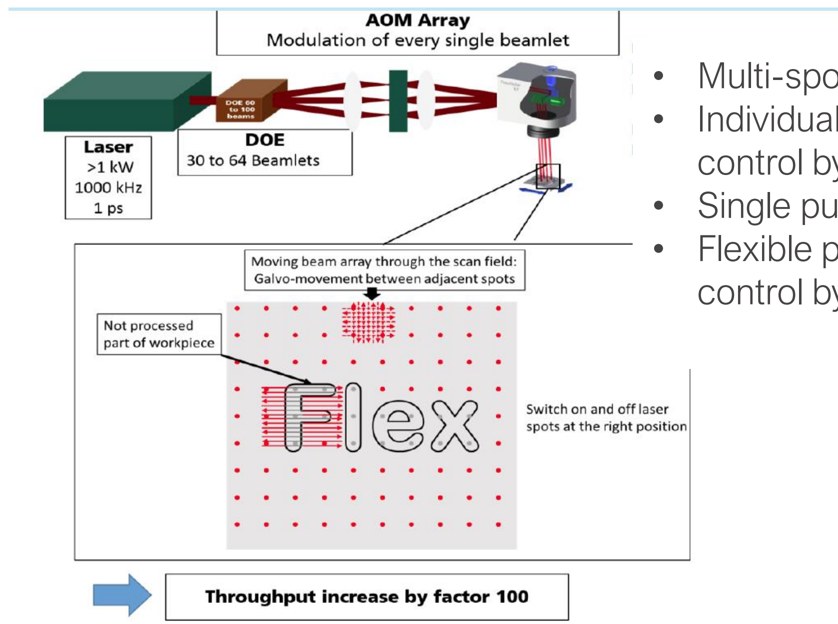
PHOTONICS PUBLIC PRIVATE PARTNERSHIP



Picture 1:
Array of multi-beams for parallelized ultrafast laser processing.
© Fraunhofer ILT, Aachen, Germany.



Picture 2:
Surface textures on tool steel fabricated by means of ultrafast laser radiation.
© Fraunhofer ILT, Aachen, Germany.



- Multi-spots by DOE
- Individual beamlet control by AOM Array
- Single pulses & bursts
- Flexible pulse/burst control by FemtoTrig®

kW fs laser with flexible controls

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MULTIPOINT

http://multipoint-project.eu/

> Objective : high throughput micro-drilling for the aerospace industry.

- Micro-drilling of large Ti panels
- Fabrication of Hybrid Laminar Flow Control (HLFC) structure
- No chemicals

Fuel consumption reductions higher than 9% on commercial planes when HLFC panels applied.

Horizon 2020
European Union Funding
for Research & Innovation

Reductions of at least 30% in the final cost in the fabrication of HLFC panels.

Less environmental impact due to the elimination of chemical post-processing procedures in the fabrication of HLFC panels.

kW fs laser with high pulse energy

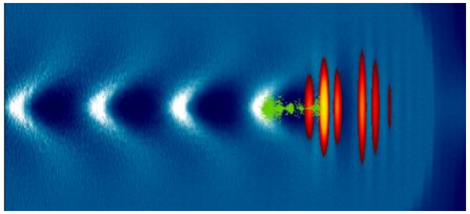
03

Secondary sources

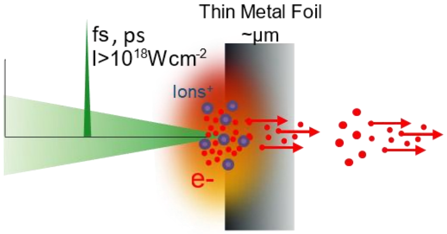
/ Ultrafast laser-driven secondary sources

Petawatt(Ti:Sa)

GeV electron sources

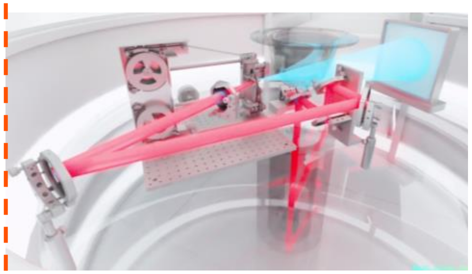


MeV proton sources

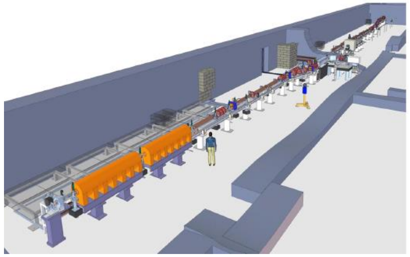


Terawatt (Ti:Sa/Yb)

LPP X-ray sources

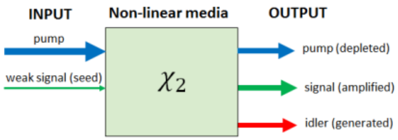


ICS X/γ-ray sources

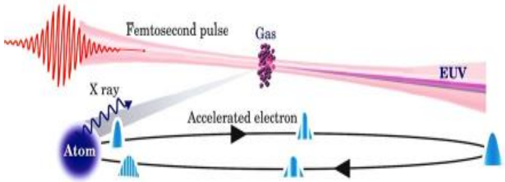


Gigawatt (Yb)

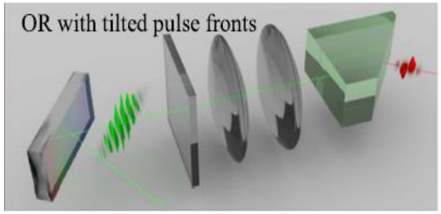
UV-VIS-MIR sources



XUV sources



THz sources



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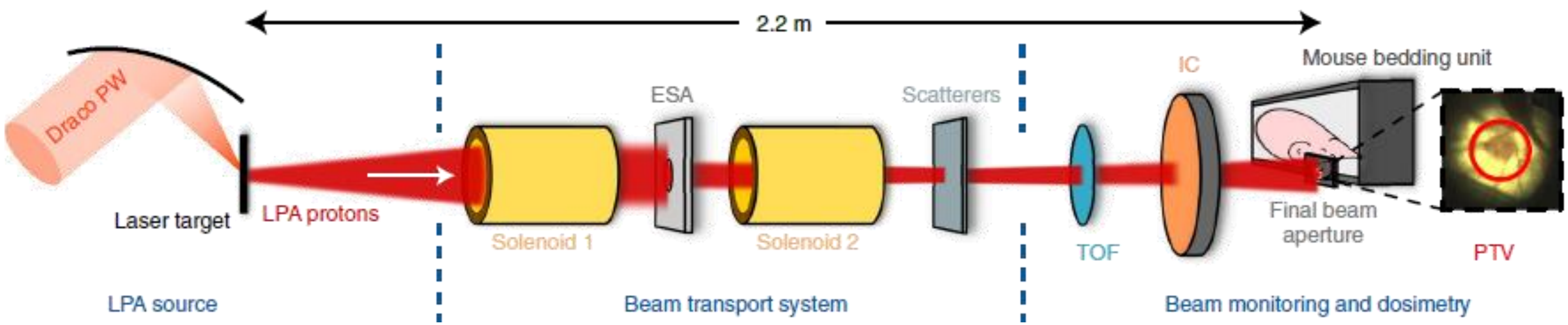
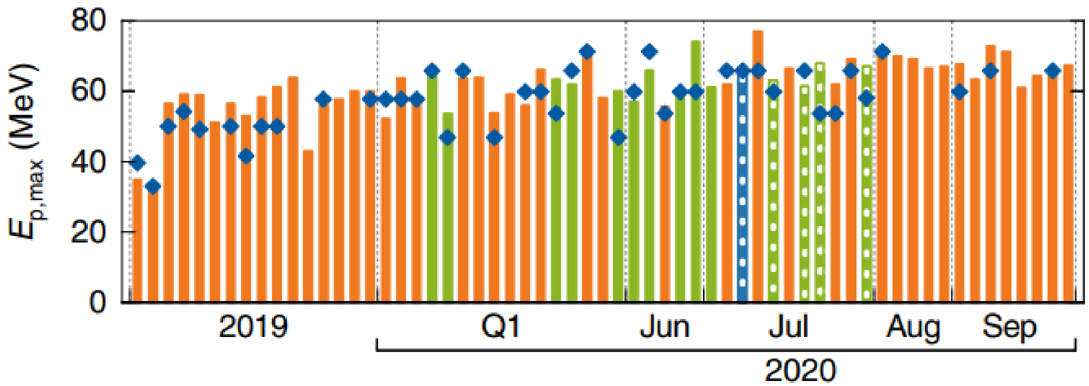
Particle acceleration with DRACO PW

HZDR HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

Tumor irradiation in mice with a laser-accelerated proton beam



Protons @ 1 PW



Kroll, F., et al., Nature Physics | VOL 18 | March 2022 | 316–322
Tumor irradiation in mice with a laser-accelerated proton beam .

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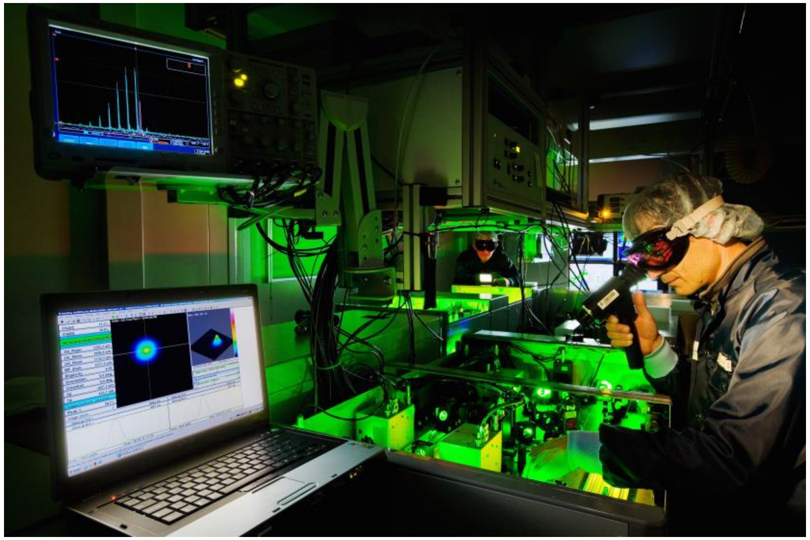
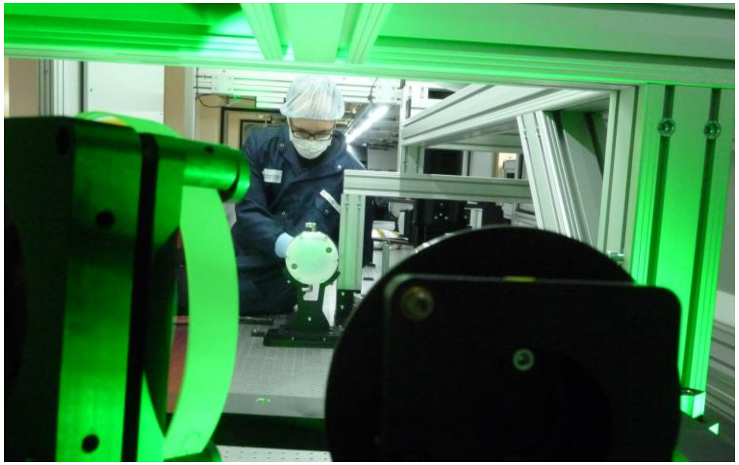
DRACO PW laser

Dual output laser (TiSa, 800nm)

- 1PW (25 J, 25fs)
  1 Hz
  Better than 10^{-12}:1 contrast
- 150 TW
  Single shot to 10 Hz



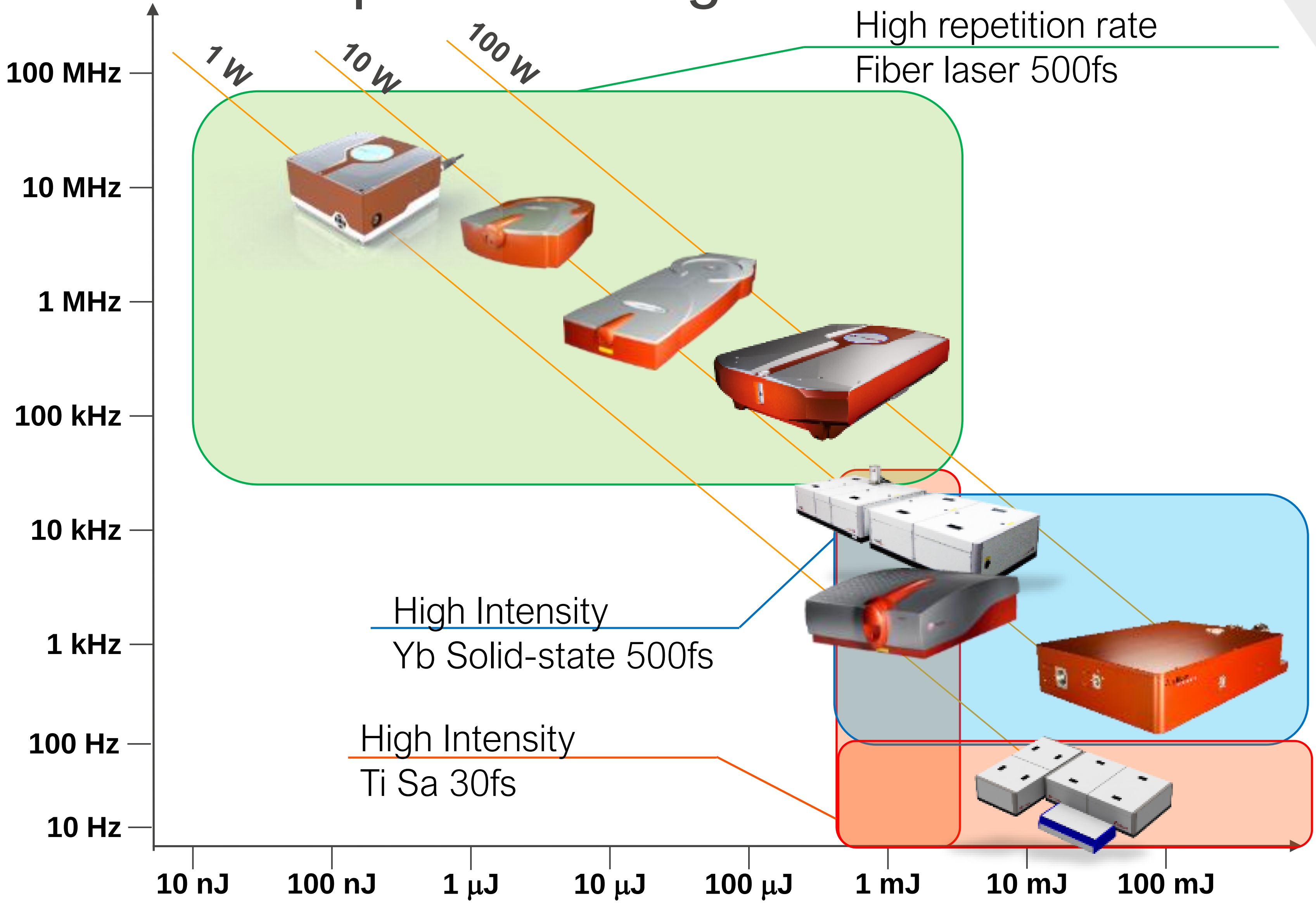


Amplitude

04

Magma portfolio

/ Ultrafast laser product range



Amplitude

/ Magma portfolio

> High energy lasers : 2mJ to 500mJ

> Short pulses <500fs, adjustable to 10ps

> High repetition rate : >100Hz

> Compact, stable and modular

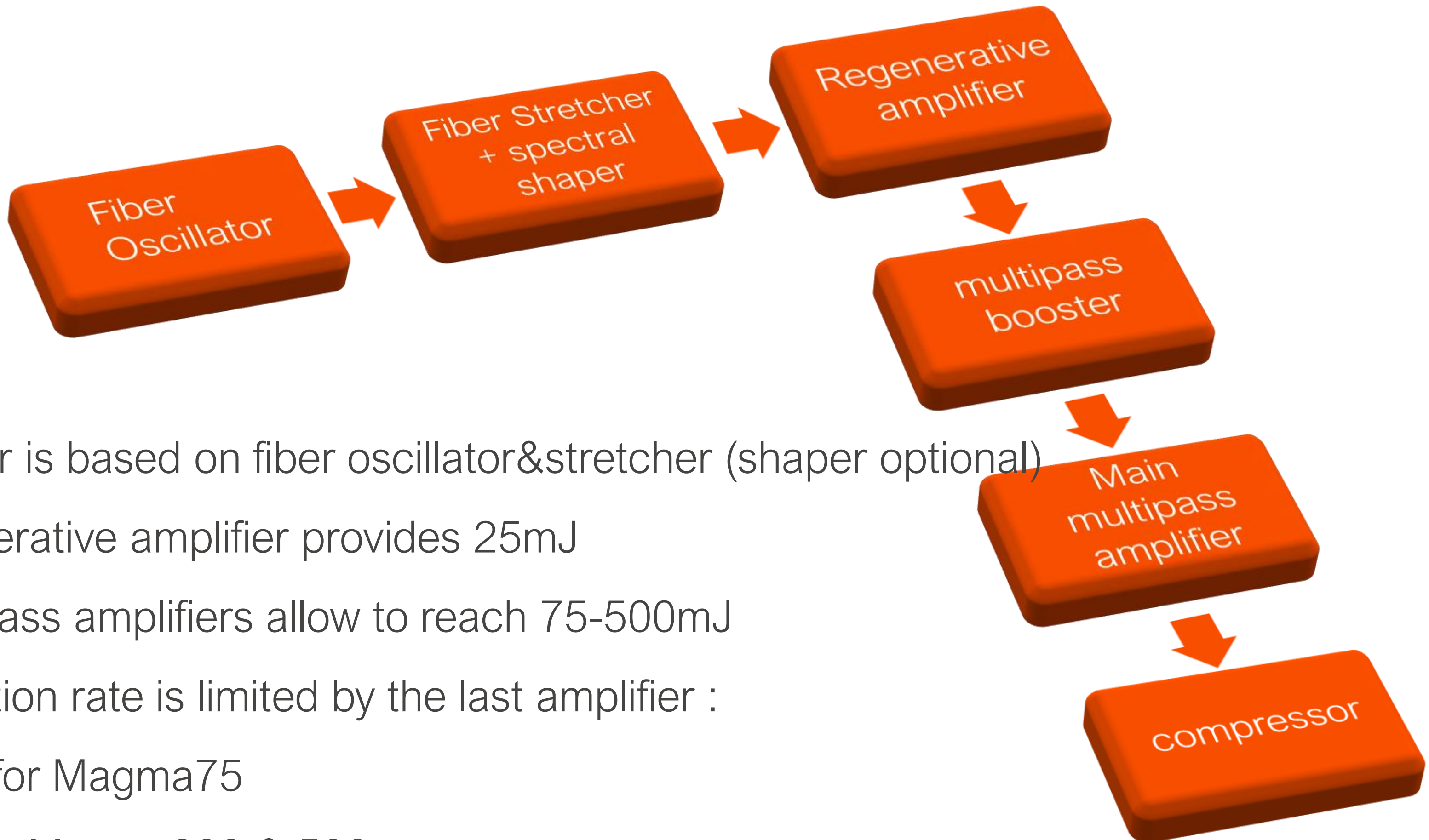
> Remote control

> Synchronizable

> High energy Green and UV

Amplitude

Magma : a modular laser architecture



MAGMA 75-500

The seeder is based on fiber oscillator&stretcher (shaper optional)

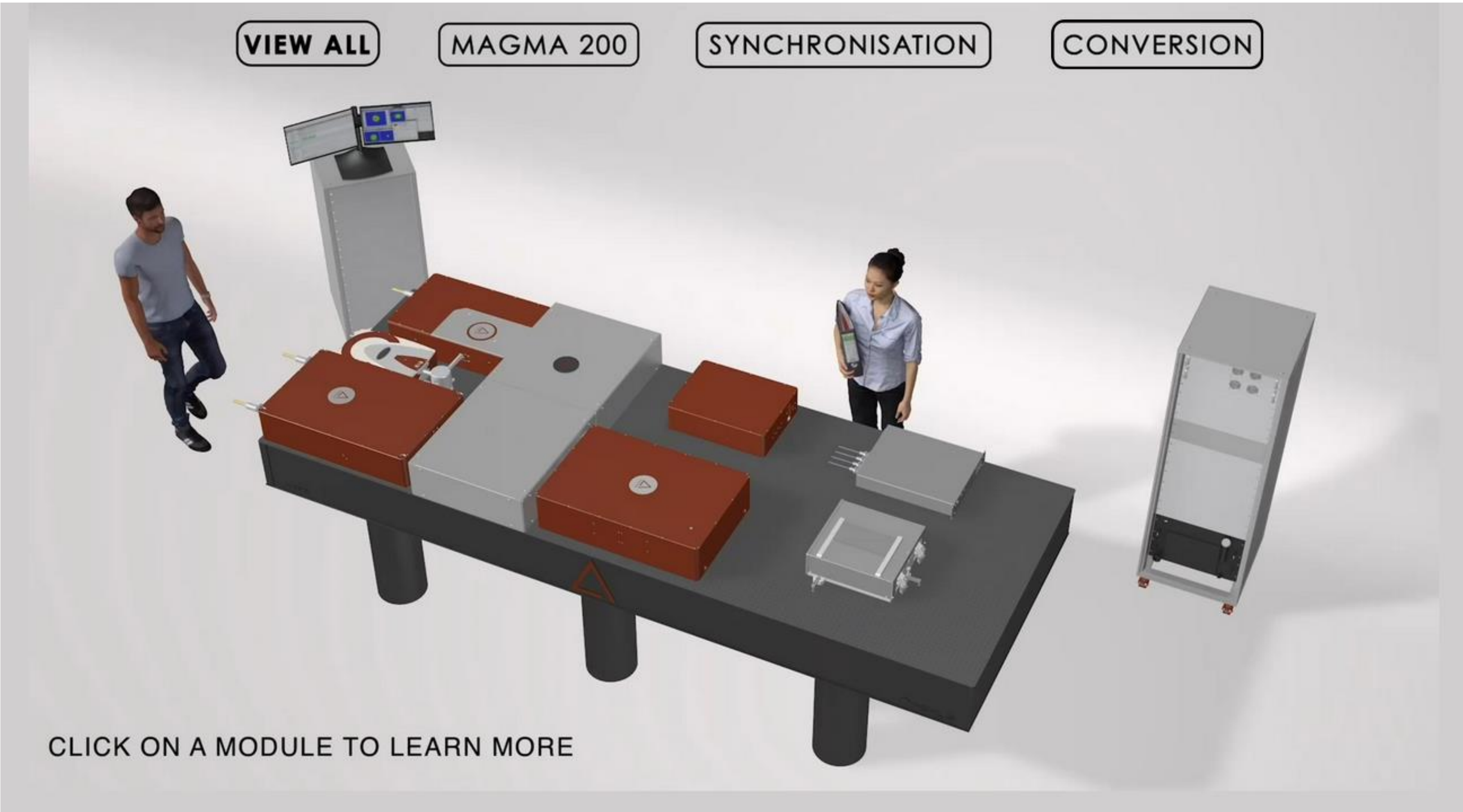
The regenerative amplifier provides 25mJ

The multipass amplifiers allow to reach 75-500mJ

The repetition rate is limited by the last amplifier :

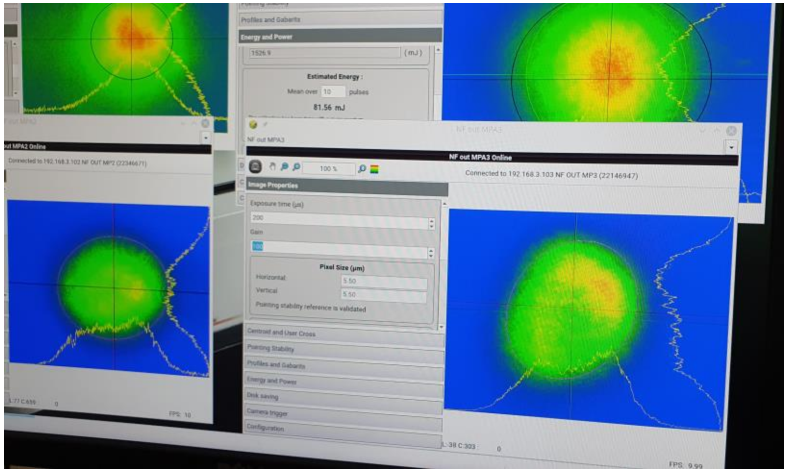
- 100Hz for Magma75
- 50Hz for Magma200 & 500

/ Magma general layout



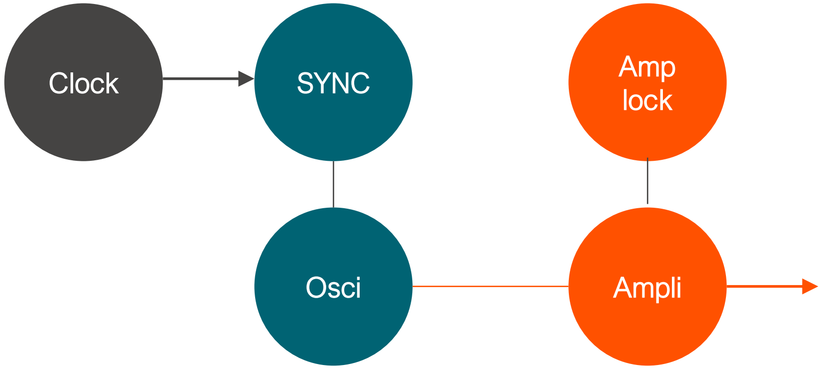
/ Control Command

- > **Monitor** relevant parameters at each amplifier stage
  - > Using CCD camera : Energy, beam profile, beam position
  - > Spectrometer : check spectral shape
- > **Secure** daily operation
- > **Adjust&Optimize** the settings : pump powers, triggering, alignment
- > **Stabilize** by active feedback on relevant parts
- > **Log** the measurements after averaging/for each pulse



/ Synchronization : SYNC & Amplock

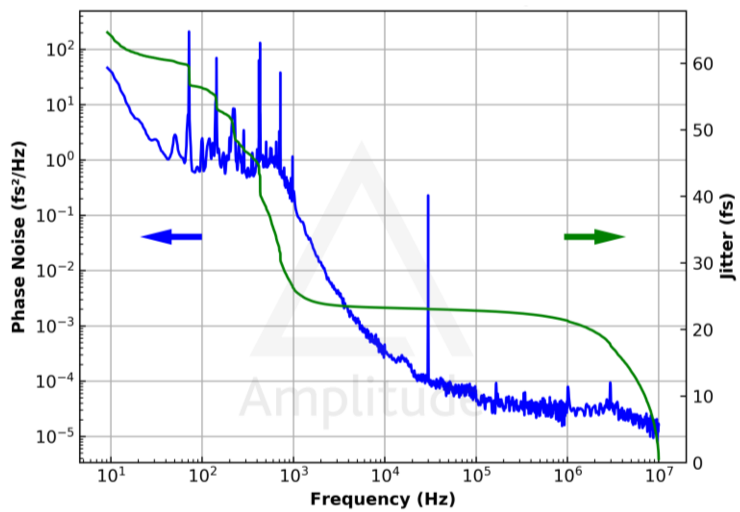
- We need to ensure the coïncidence of the amplified pulses with the other particles
  - Electrons in accelerator
  - Photons in OPCPA / pump-probe experiment
- A common clock is distributed, RF or optical
- SYNC : synchronization of the oscillator with the clock
- AMPLOCK : compensate drift induced by the amplifier

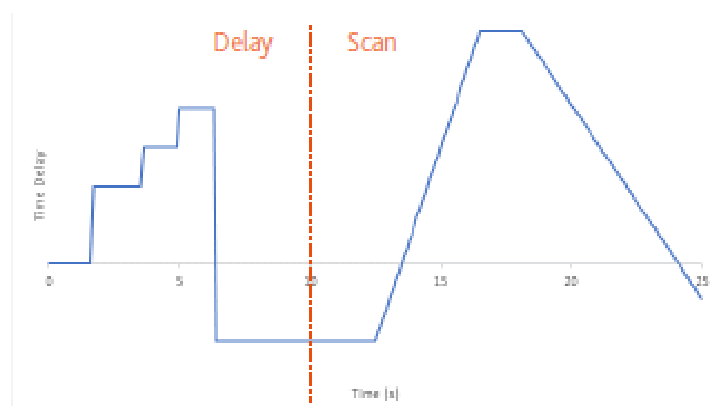


Amplitude

/ Synchronization : SYNC

- Standard fiber oscillator with additional actuators
  - Fast feedback (piezo) + slow feedback (translation stage)
- Electronic synchronization on RF or optical reference
- Jitter : <250fs rms from 10Hz to 10MHz (measured with SSA)
- Remote delay line
  - Fixed delay, single to infinite steps of 150fs
  - Scanning from 250fs/s to 250µs/s





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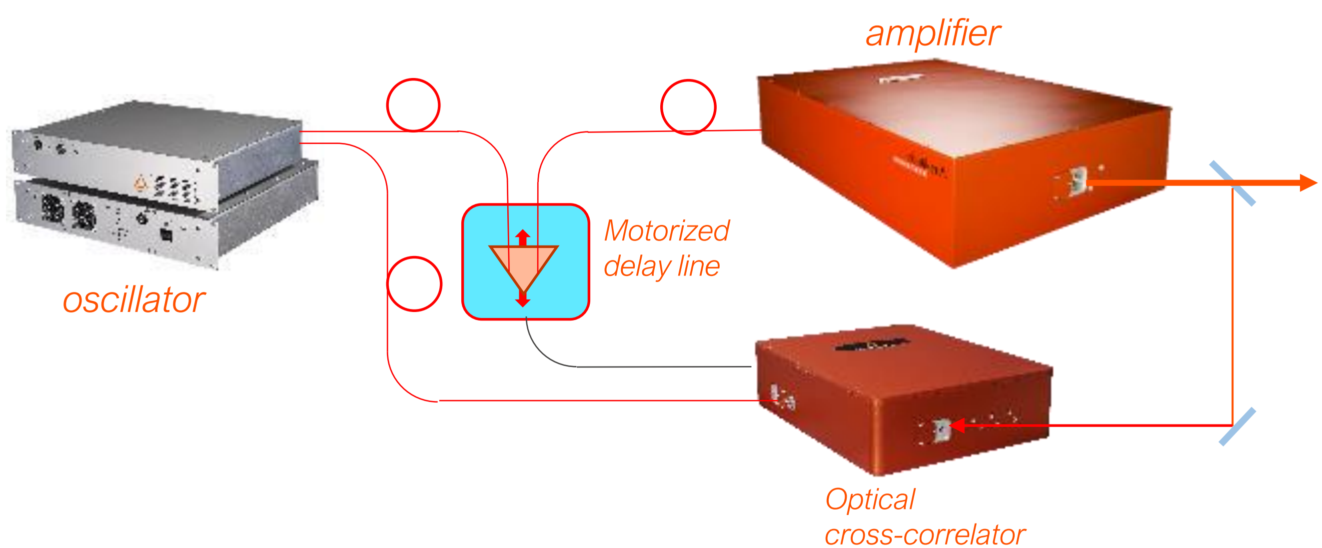
/ Amplock : compensating amplifier drift

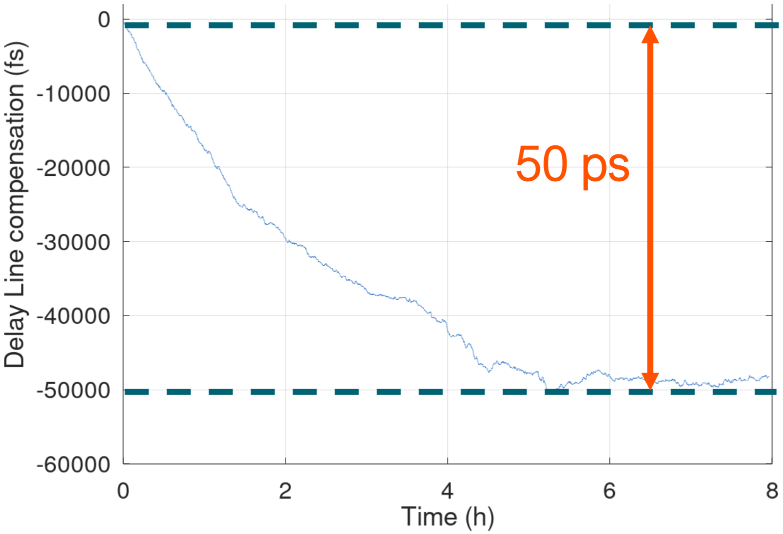
- Amplifiers introduce additional delay
- Thermal drift induces several ps /°C
- Use optical mixing to measure the time delay, and compensate with slow delay line
- Performances : <30fs rms



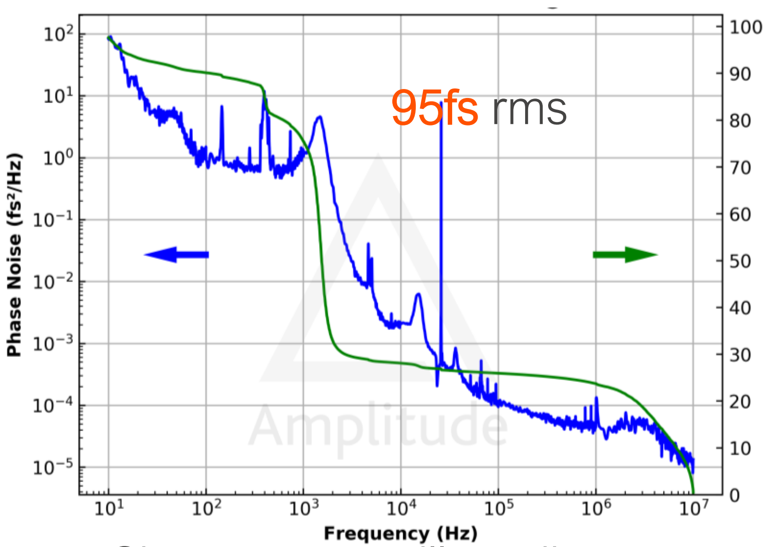
Amplitude

/ Examples

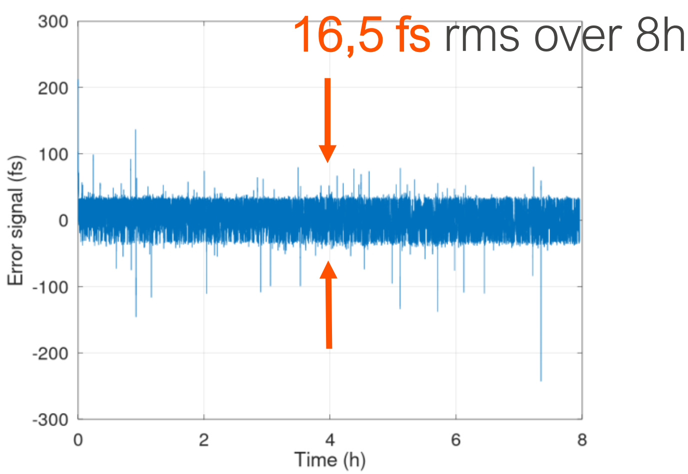
- Magma25#2



Long-term intrinsic amplifier drift



Short-term oscillator jitter

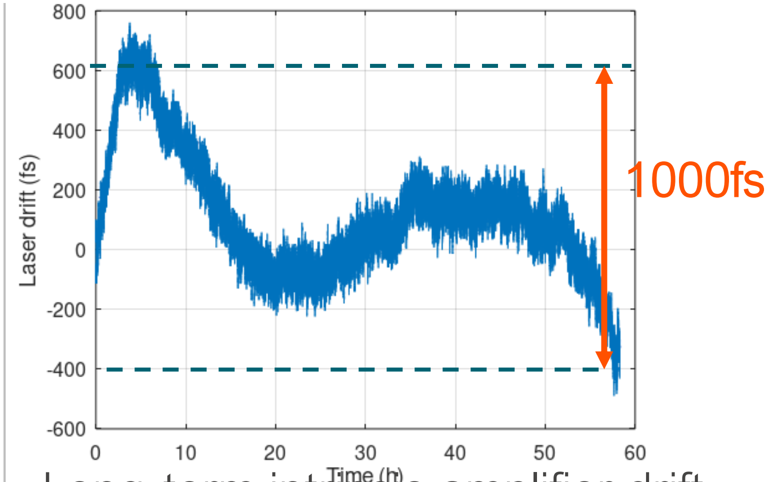


Long-term amplifier jitter

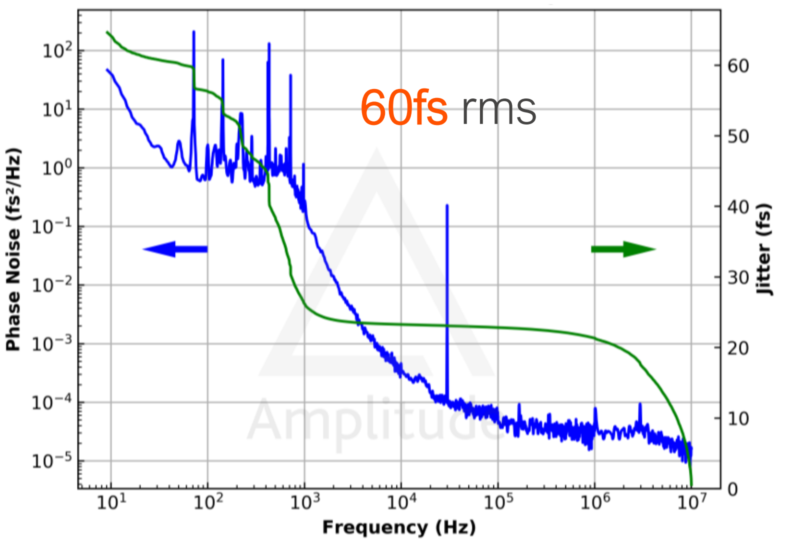
Amplitude

/ Examples

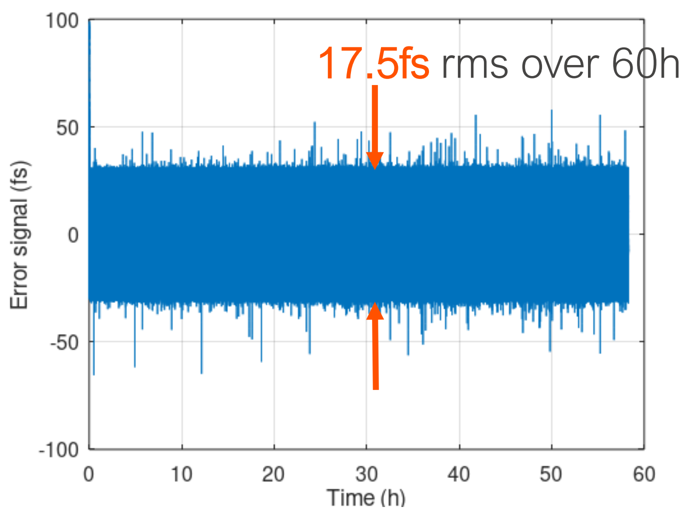
- Tangerine#1



Long-term intrinsic amplifier drift



Short-term oscillator jitter



Long-term amplifier jitter

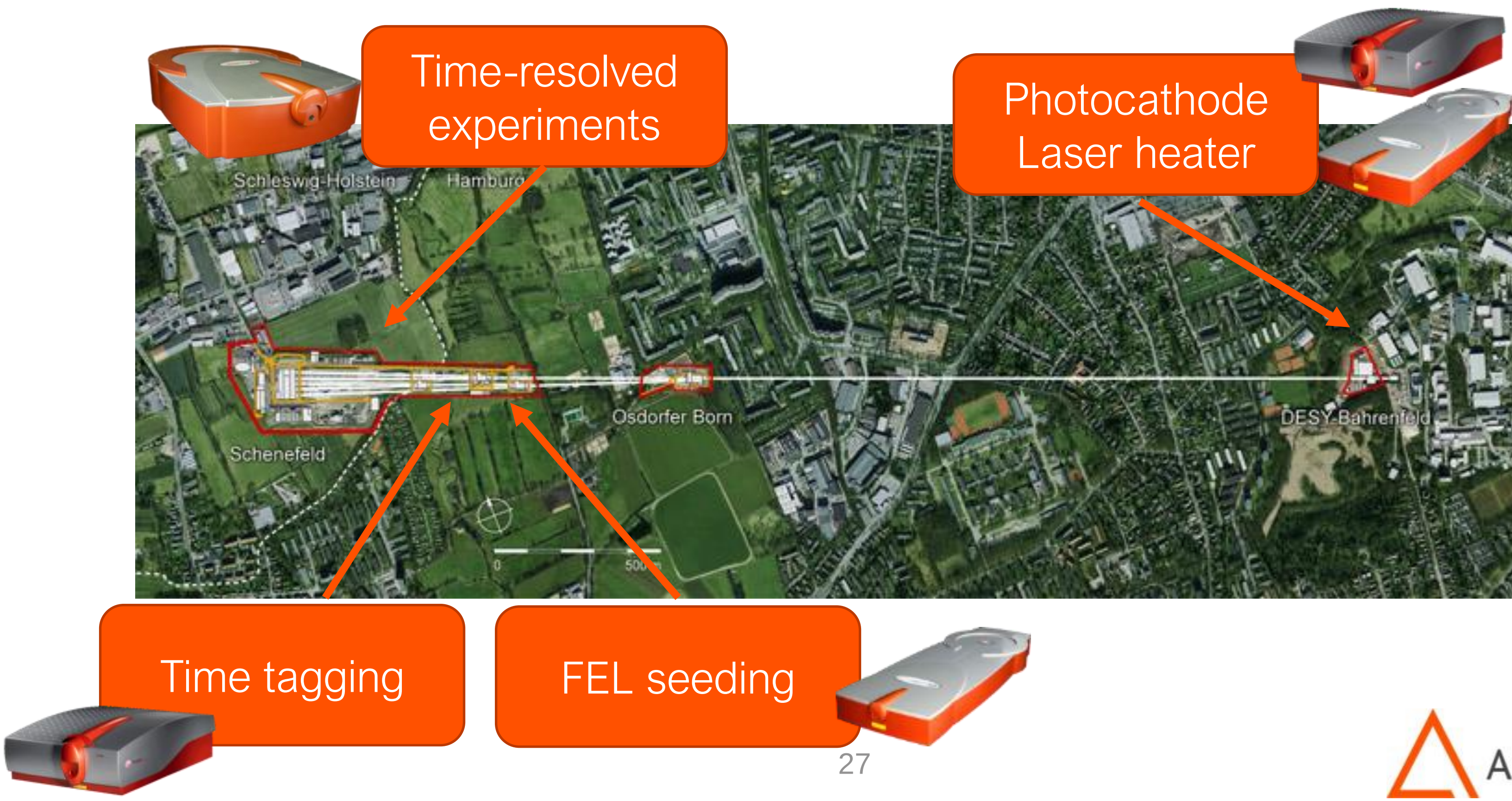
Amplitude

05

Accelerator-based X-ray sources FELs and ICS

/ Free Electron Lasers (FELs)

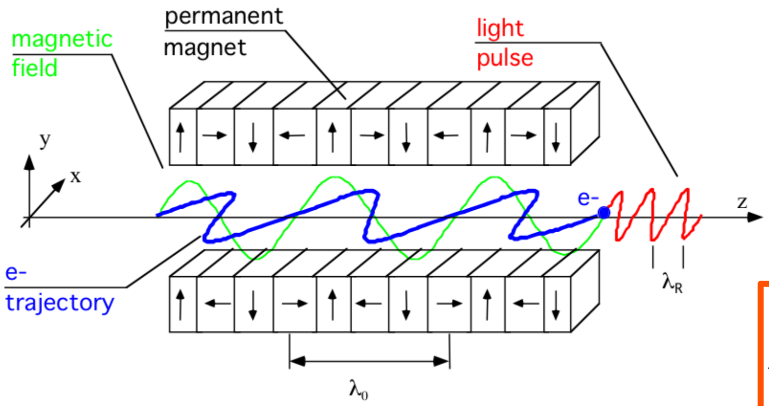
- Latest generation, few km-long
- Trend towards 1MHz operation using superconducting LINAC
- Precise synchronization is a must have (100fs to few fs jitter)



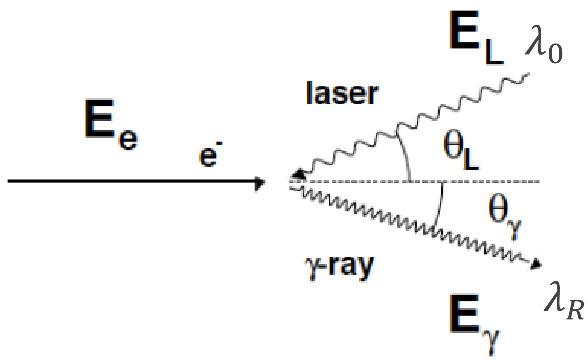
Amplitude

/ X-ray Compact sources

Synchrotrons & FELs



Inverse Compton Scattering (ICS)



$$\lambda_R \approx \frac{\lambda_0}{4\gamma^2}$$

Magnetic Undulator = centimetric period

Optical Undulator = micrometric period

X-FEL : 17,5 GeV electrons = 2km LINAC

X-ICS : 100 MeV électrons = 5-10m LINAC

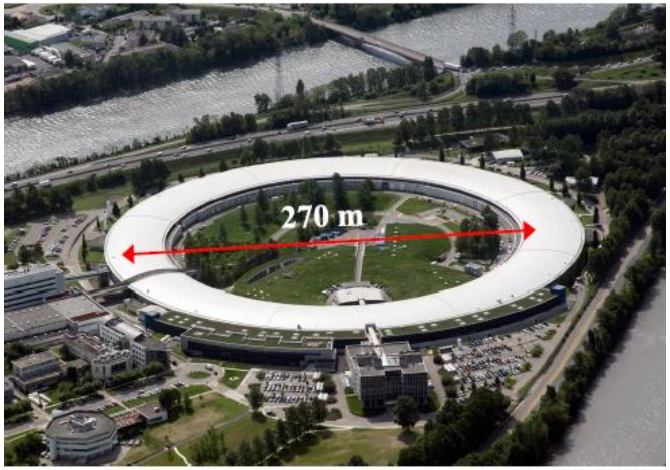
ICS allows to generate X/γ-rays with 100 times reduced electron energy

➡ Compact systems

Amplitude

/ X-ray Compact sources

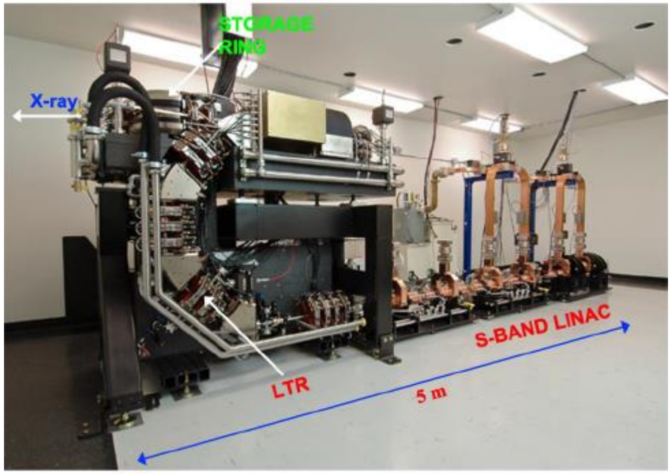
Synchrotrons



ESRF: 6 GeV e- / 844 m Circumference
10-40 keV X-rays

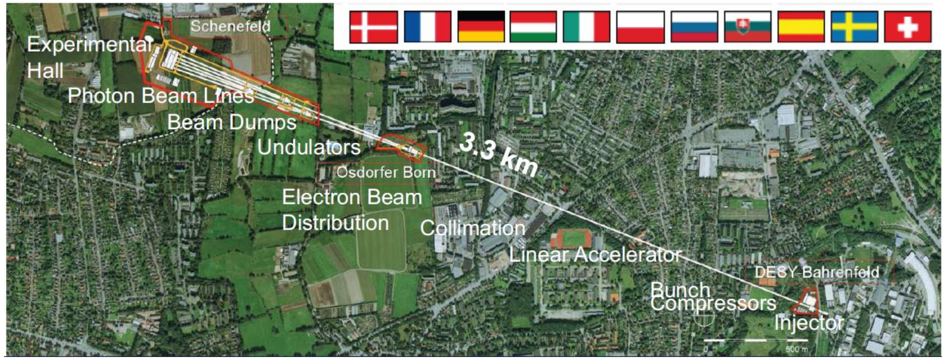
→

ICS - Ring



CLS@LTI: 40 MeV e- / 5x4 m² footprint
30-40 keV X-rays

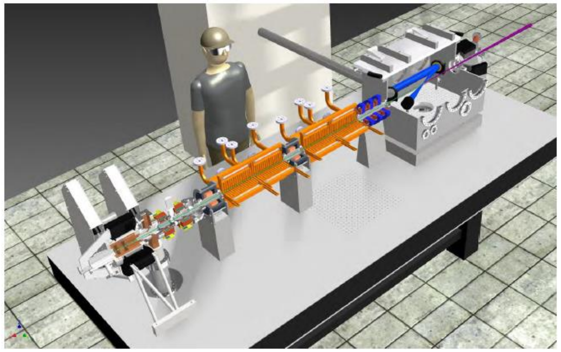
X-FELs



Eu-XFEL : 10GeV e- / **3,3km** long
3-25 keV X-rays

→

ICS - Linac



Smartlight : 30MeV e- / **4m** long
10-40 keV X-rays

Bring the Sources in the Hospital/Factory !

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/ ICS sources

~30 projects ongoing worldwide

Need compact&reliable ps sources

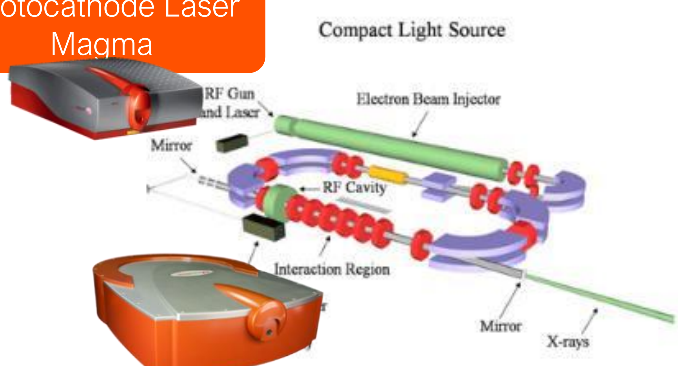
Storage ring

- High rep rate
- Low energy laser
- Fixed energy

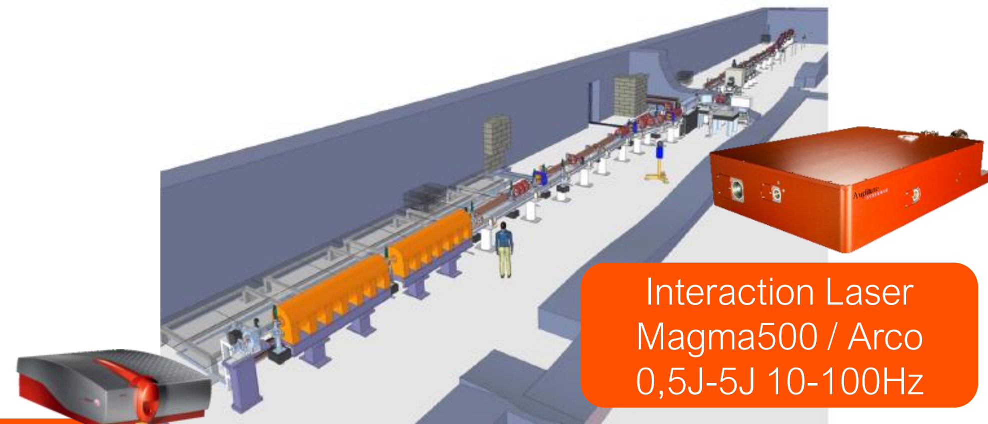
Linear accelerator (LINAC)

- Low rep rate (~100Hz)
- High Energy Laser
- Wide energy tunability

Photocathode Laser Magma



Interaction Laser Tangor



Interaction Laser Magma500 / Arco 0,5J-5J 10-100Hz

Photocathode Laser Magma

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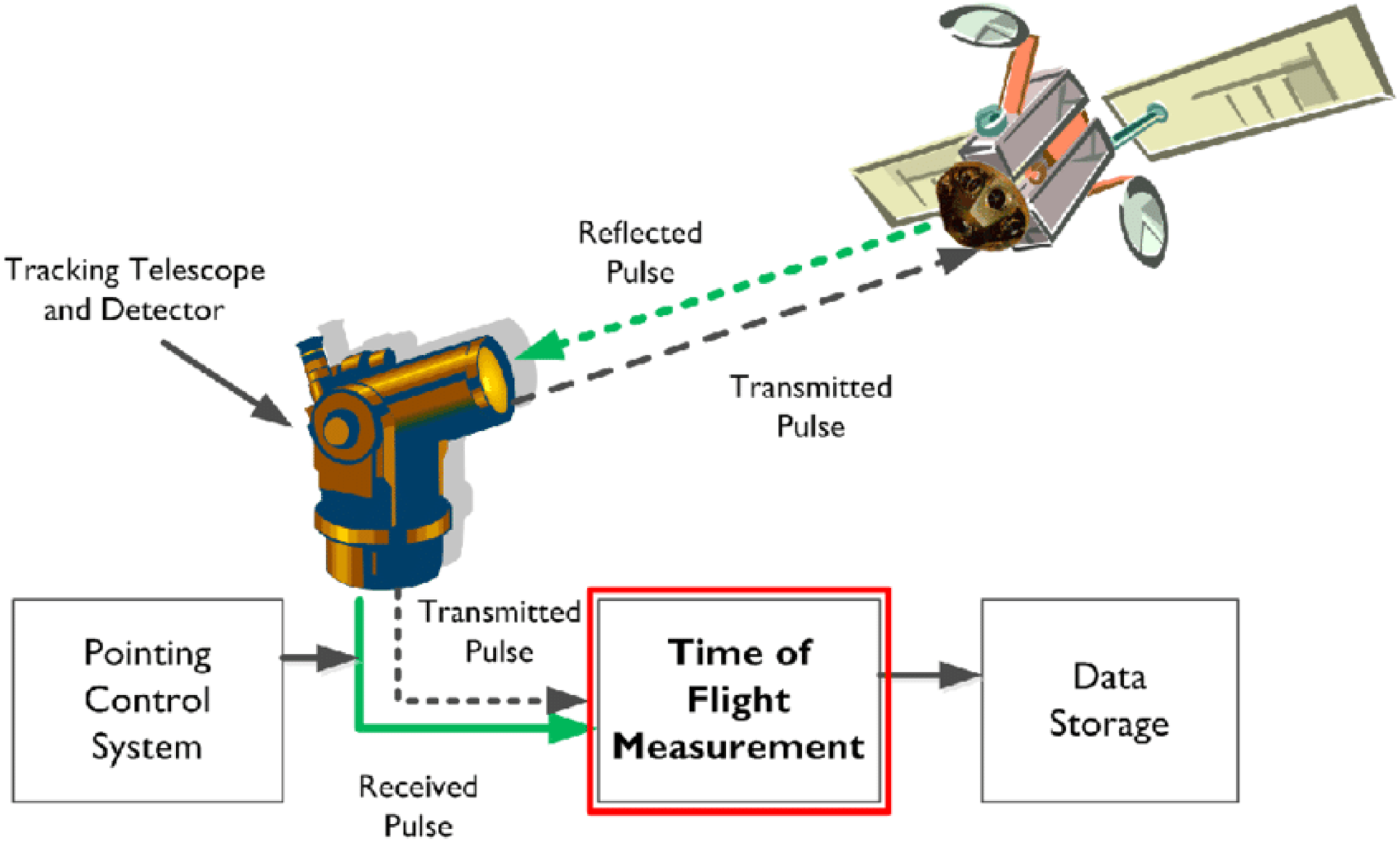
06

Satellite Laser ranging

/ Satellite Laser Ranging

Current laser parameters : 1-5mJ IR/green 5-15ps kHz



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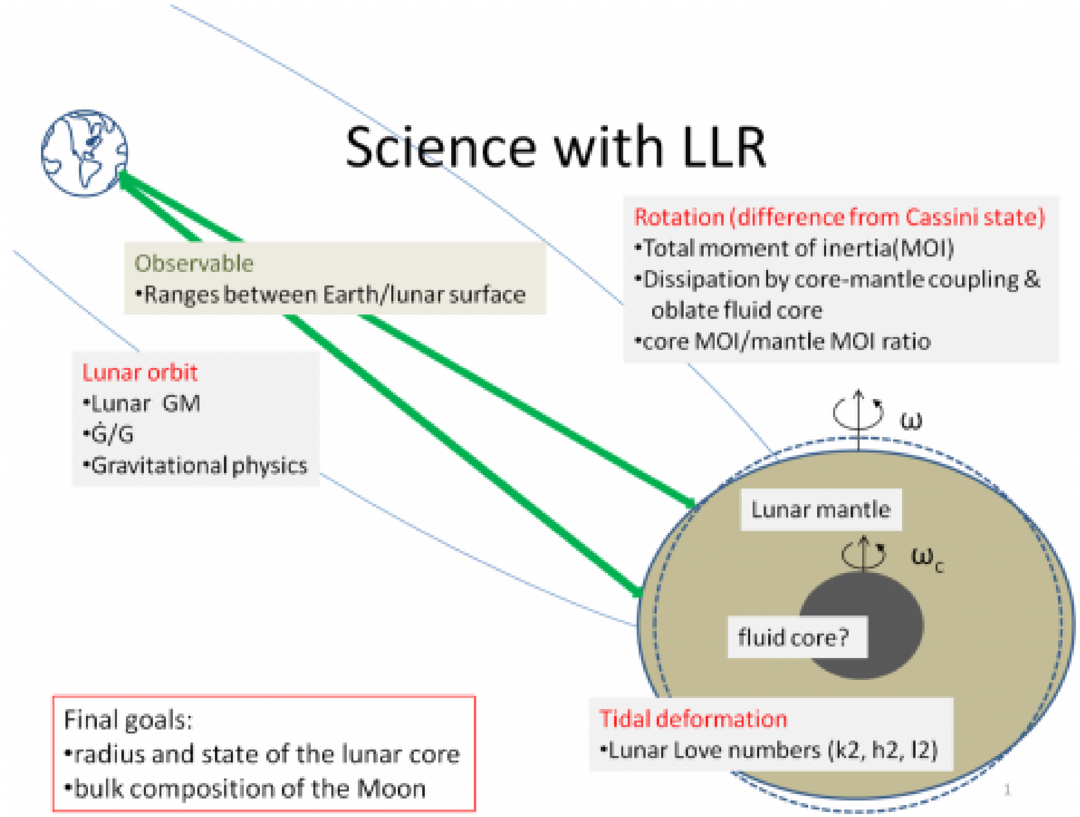
/ Lunar Laser Ranging

Current laser parameters : 100mJ IR/ green 150ps 10Hz
Synchronized with geodesic network



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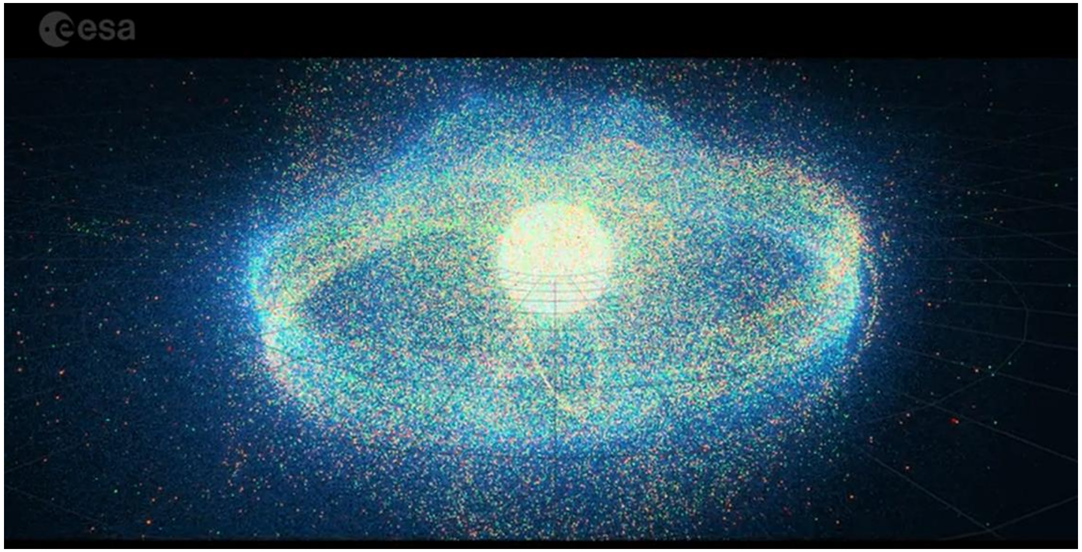
/ Space debris ranging

Current laser parameters : 0,5 to 5J ~5ns?



Amplitude

/ Improving the ranging precision

Tendancy : improve resolution to 1mm

- Higher repetition rate
- shorter pulses
- Synchronized pulses

Our possible offer :

- Magma200 + SHG : 100mJ 50-100Hz 20ps 515nm (+IR if needed)
- Magma2-25 + SHG : 1-10mJ 1kHz 1-10ps 515nm (+IR if needed)
- Tangor + SHG : 0,25mJ 200kHz 5ps 515nm (+IR if needed)
- Femtosecond synchronization to RF reference (linked to GPS)