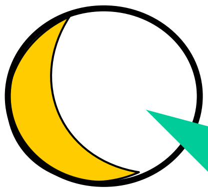
Aiming towards compact versatile ranging lidars

Grégoire Martinot-Lagarde (OCA = Observatoire de la Côte d'Azur)

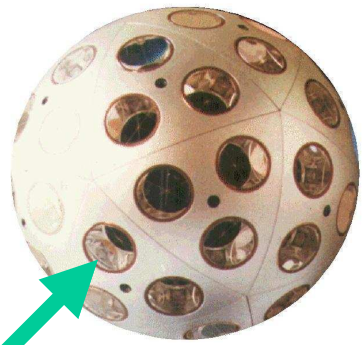
MéO laser ranging station (OCA\ Calern)



The Moon

alt. ~ 350 000 km

Stella satellite
alt. ~ 800 km
(diameter = 20 cm)



200 mJ / pulse train
of ps Nd-Yag laser

=> mean precision ~ 200 ps

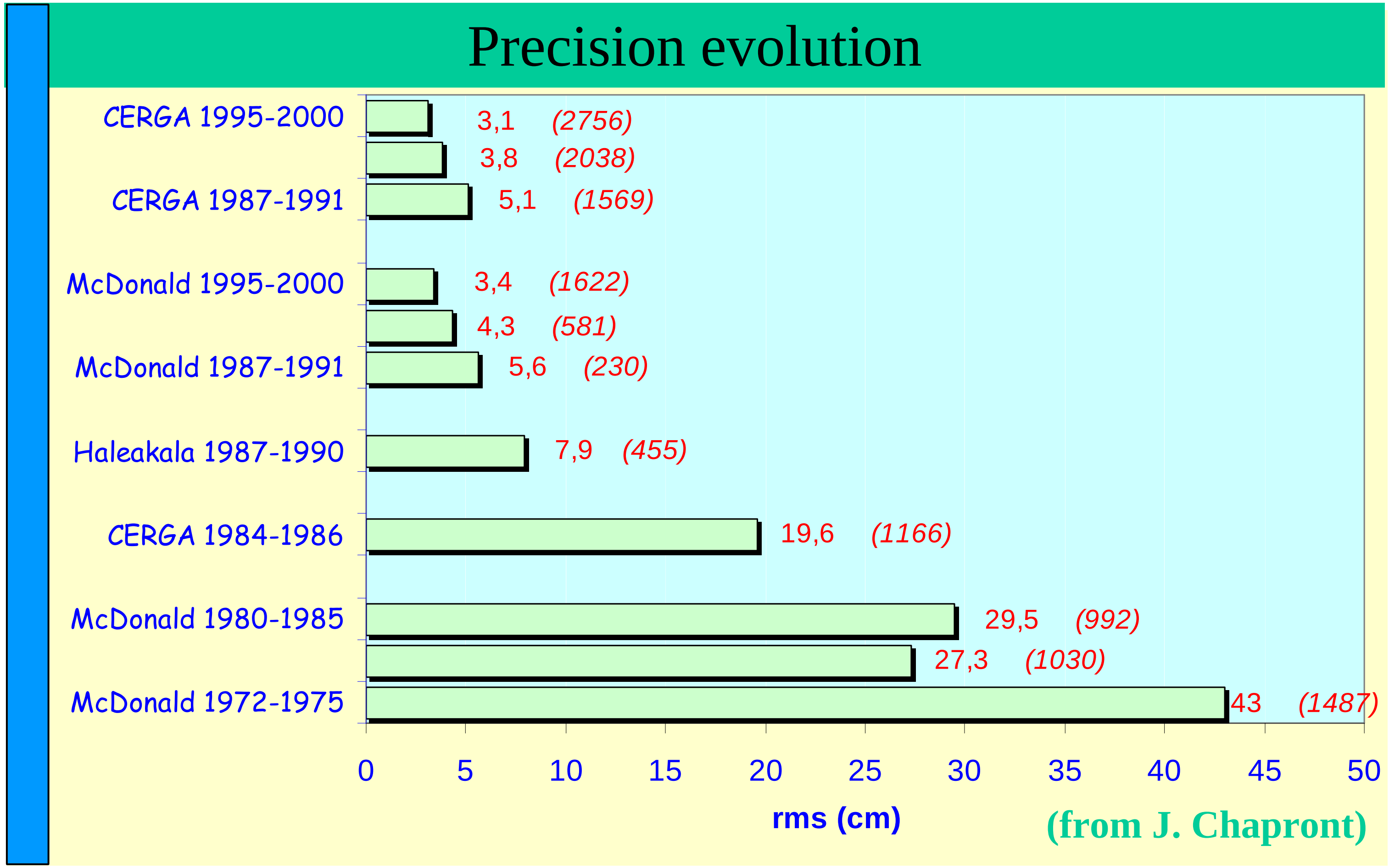
(200 ps ⇔ 3 cm = earth_moon / 10^{10})

a few mJ
of ps Nd-Yag
laser

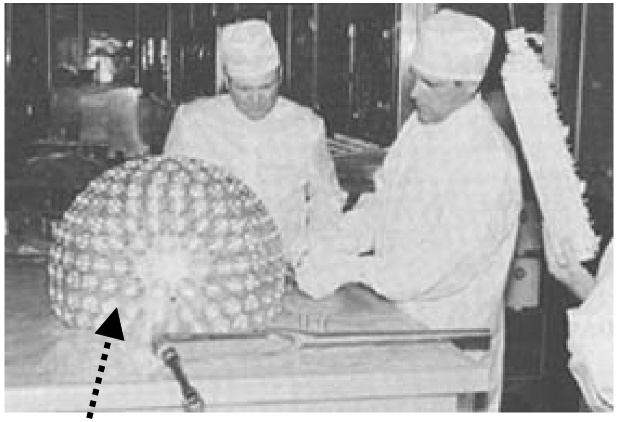
**⇒ sensitivity
to be tested**

MéO Telescope aperture = 1,5 m at Calern Observatory (altitude = 1300 m)

Lunar laser ranging results improvements



Calern laser ranging stations complementarity



Lageos echos
~ 1000 000 Moon echos

as **10^6** ~ [altitude ^{4} / surface]
~ [100^4 / 100]

(1000 cm²)

Lageos
(10 cm²)

400 | 4000 | 40 000 | 400 000

Altitudes (km)

The Earth
(radius =
6400 km)

Métrologie Optique (MéO = ex-LLR)
200 mJ emitted in 4¨ with $\Phi_{réception}$ = 1,5 m

MéO sensitivity = 100 000 FTLRS one
=> Moon echo = 1% ⇔ Lageos echo = 10%

FTLRS = French Transportable
Laser Ranging System)
20 mJ emitted in 40¨ with $\Phi_{réception}$ = 15 cm

⇒ MéO range = Moon
⇒ FTLRS range = Lageos

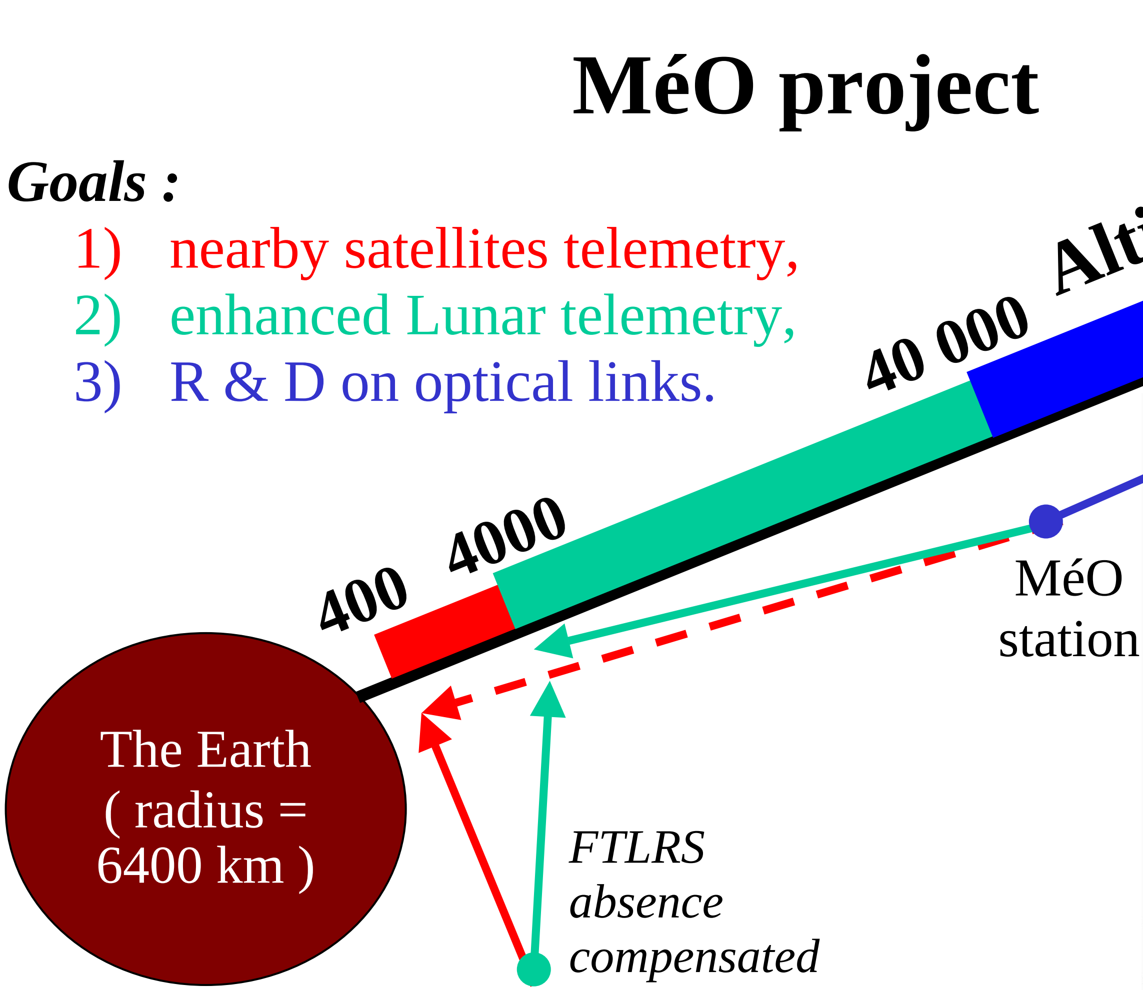
6 research directions to enhance stations range and precision

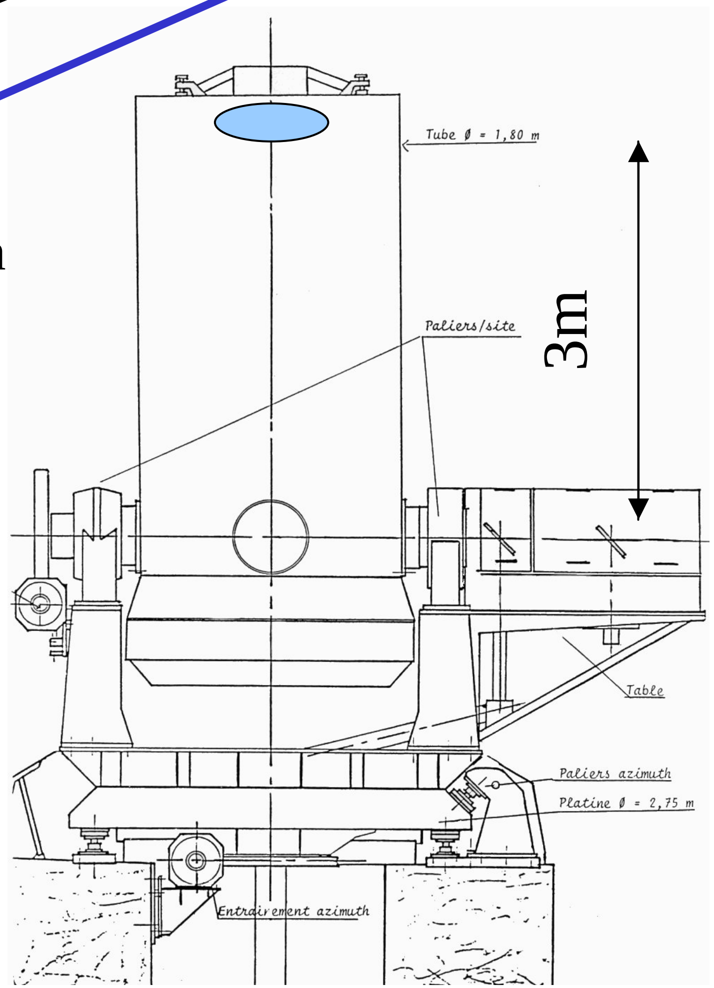
1) Stations improvements,
2) Target enhancements,
3) Data post-treatment : mixing of Laser Ranging results (ILRS),
4) Comparison with complementary technologies (GPS…),
5) Post-treatment incorporating complementary technologies (GPS, GLONASS, VLBI...) to improve the substraction of unwanted bias (local earth tectonic movements) from the longitudinal laser ranging results (for large scale studies),
6) New laser ranging concepts (T2L2, TIPO)…

MéO project

Goals :

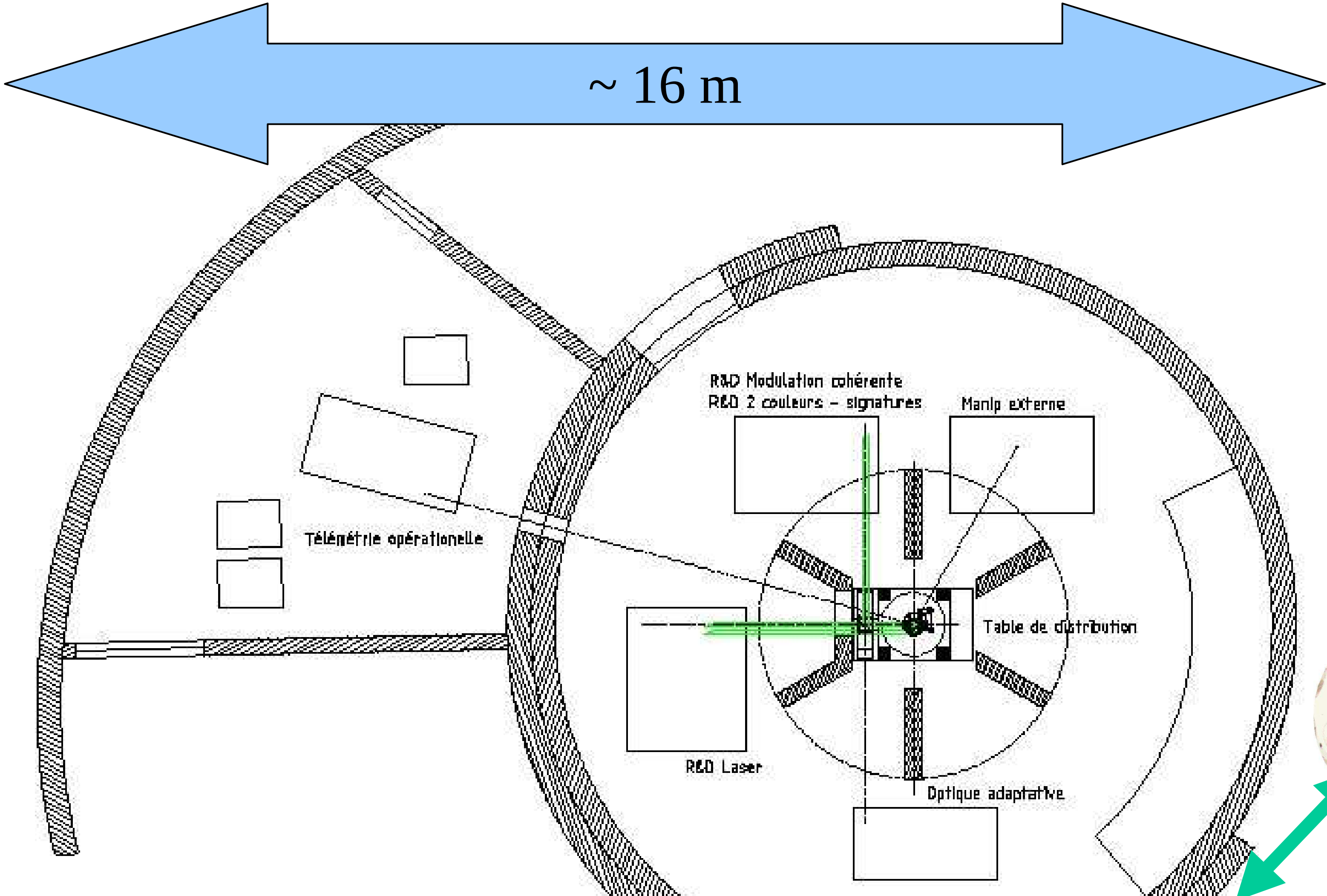
1) nearby satellites telemetry,
2) enhanced Lunar telemetry,
3) R & D on optical links.

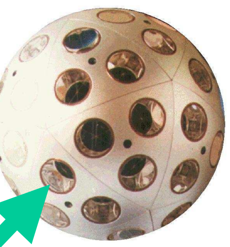




How :

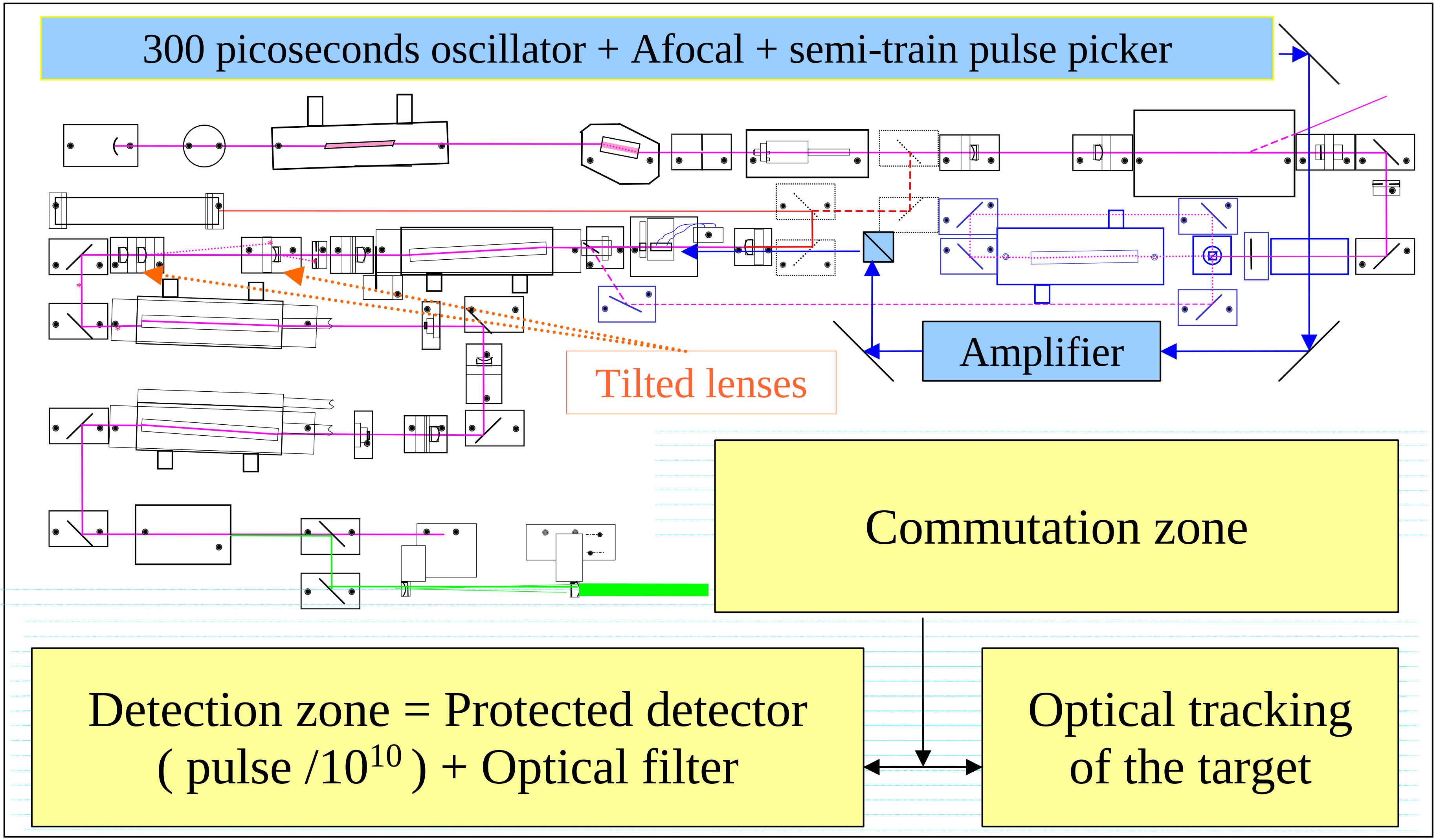
1) telescope speed enhancement (x 10),
2) 2 (3) complementary lasers,
3) optical commutation enhancements,
4) focal laboratory for visitors instruments





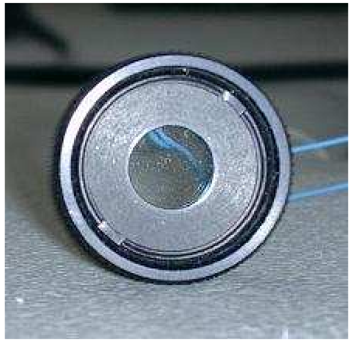
Ground floor of the optical laboratory

Méo laser table = 2,4 m x 1,4 m



scale 1/10

from J-F. Mangin (OCA)



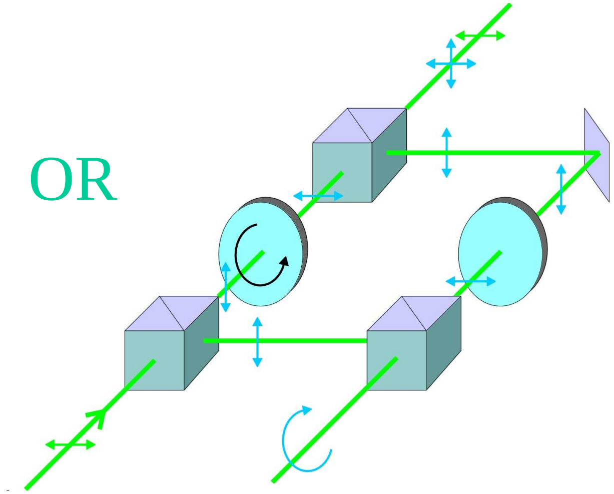
FLC of Boulder
Nonlinear Systems

Optical commutation technologies

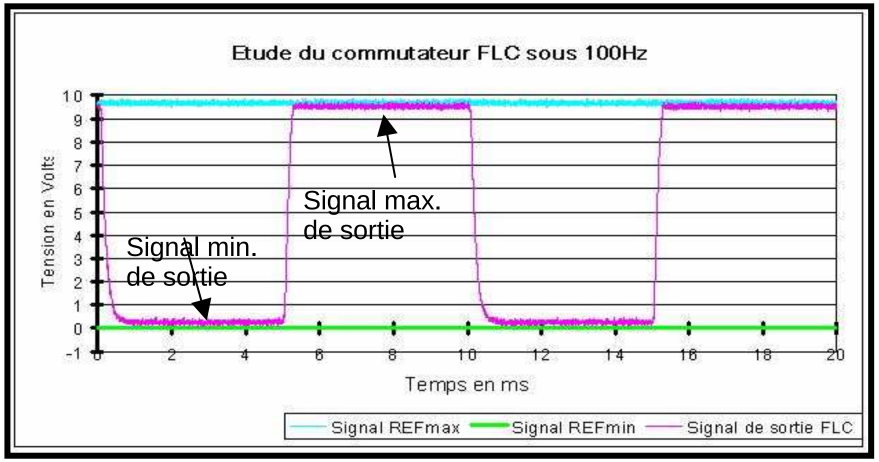
target at 400 km ⇔ time of flight = 2,6 ms)

Commutation with dichroic + shutter

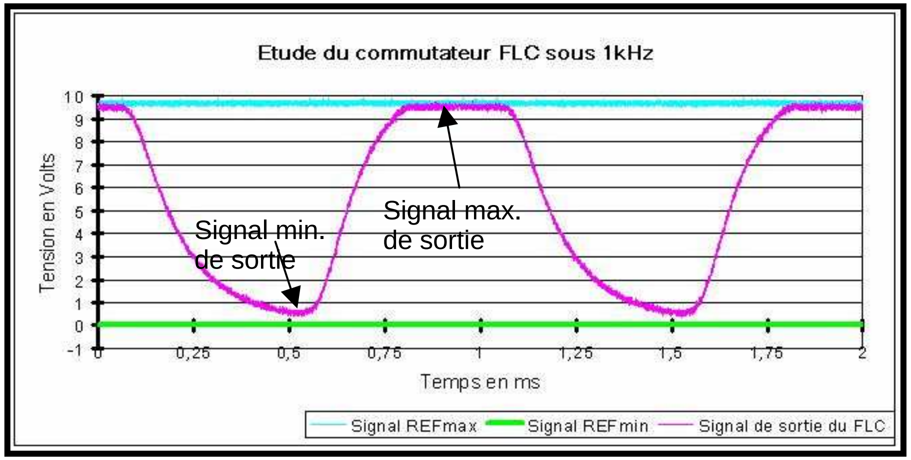
OR



- Ferroelectric Liquid Crystal FLC :
  - polarisation rotation (90°) in +/-5 Volts
  - large diameter (up to 100 mm)
  - Dammage threshold : 50 mJ/cm² @ 200 ps
  - Less than 1 ms commutation from 3% du flux to 97% of the flux



=> Good commutation at 100Hz

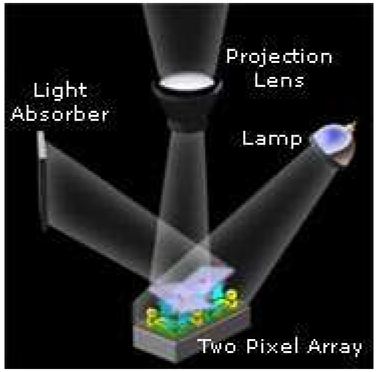


=> Commutation limit = 1 kHz

- Pockels cells:
  - Small diameter ~ 20 mm at QUANTUM Technology, inc,
  - Dammage threshold ~ 2 J / cm² ~ twice FLC one),
  - Less than 1 ns of commutation time from 0,1% à 97% du flux.
- « DLP = Digital Light Processing » micro-miroirs oriented at 12° ± 1° :
  - Intermediate price :

    FLC ~ 1500 € < DLP ~ 3000 € < Pockels ~ 7600€
  - commutation in 1 ns from a

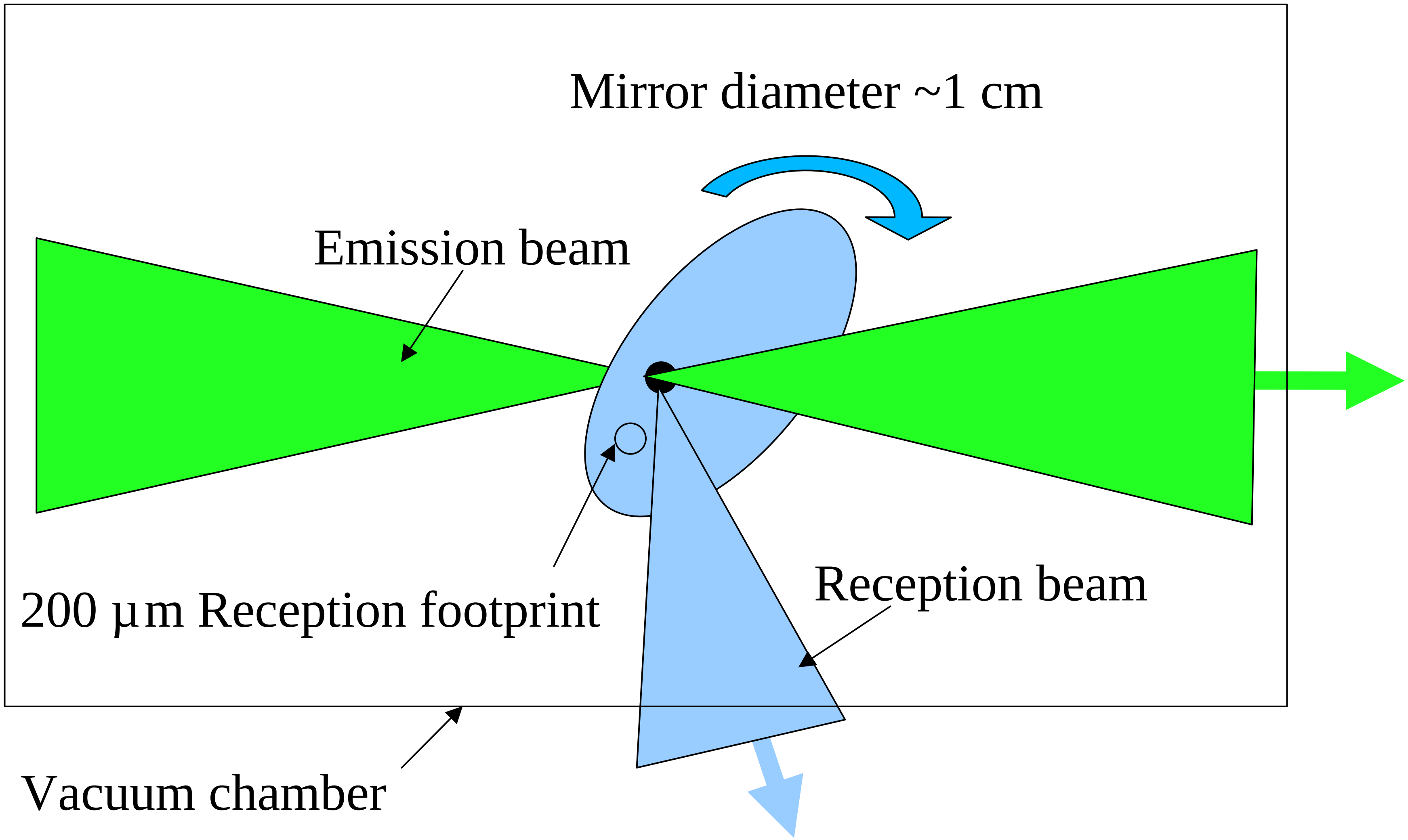
    « dark state » to a bright one (97%)



DLP

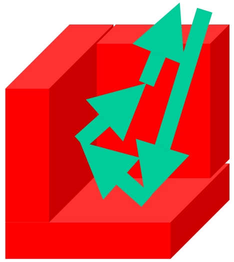
=> What about going back to a specific mechanical solution

Mechanical « miniaturised » commutation solution



For kHz commutations, a few holes could be realised…

Target enhancements



Hollow corner cube

- no refractions and optical loss
- self oriented and lightened…

« Nearby » satellites

Corner cubes surf. ~ 10 cm²

« Far » satellites

Reflectors of ~ 100 cm²

« empty » space

400 4000 40 000 400 000

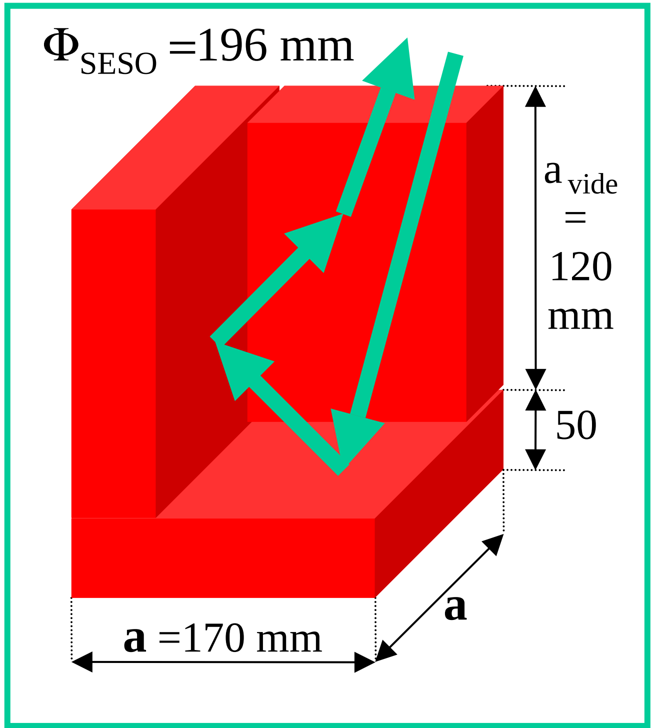
Altitude (km)

S. ≥ 1000 cm² (1969-72),

The Earth (radius = 6400 km)

- **Galileo** : 23600 km , 1 hollow cube (2008),
- **Jason 1-2** : 1200 km , 9 oriented corner cubes (2001-8),
- **Stella** : 800 km , 48 kg , 20 cm , 60 corner cubes (1993),
- **Lageos** : 5900 km, 400 kg, 60 cm, 426 corner cubes, (76).

Hollow corner cube



* Perfect (unique) spatial reference point,

* Diffraction limited by this big aperture,

* No thermic deviation » (silicate bonding),

* Field of vue up to ± 30 degrees (± 60 degrees for plein corner cubes
>> Galileo useful field of vue = ± 13 degrees,

* Aberration of speed correctable with mirrors angles ≠ 90˚,

lightweight mirrors are necessary for λ / 10 surface quality :

- Hollow_cube weight = 2 x [plein_ cube ($a_{plein} = 3^{1/2}$ x 120 mm)] weight
- but 30 to 65% ligthening => extra-costs and breaking risks...

Conclusion

We are currently developping a compact optical instrument for **O**ptical **ME**trology (**MéO**) with a range dynamic of 1000

(Moon orbit ~ 400 000 km >> minimal orbit satellites ~ 400 kms).

Our commutation final choice is still under discussion, as we intend to use intense (~1J/m²) and rapid (~100 Hz) lasers.

We then have to anticipate for wavelenghts evolutions.

Lets also foresee some station versatility with **future R&D** (Iliade), and with **invited experiments**, taking advantage of our powerful laser + astronomical telescope (∅1,5m).