

2012 IEEE International Frequency Control Symposium

Renaissance Baltimore Harborplace Hotel ~ Baltimore, MD, USA ~ May 21-24, 2012

ULISS project – First comparison of two cryocooled sapphire oscillators at the 10^{-15} level

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Outline

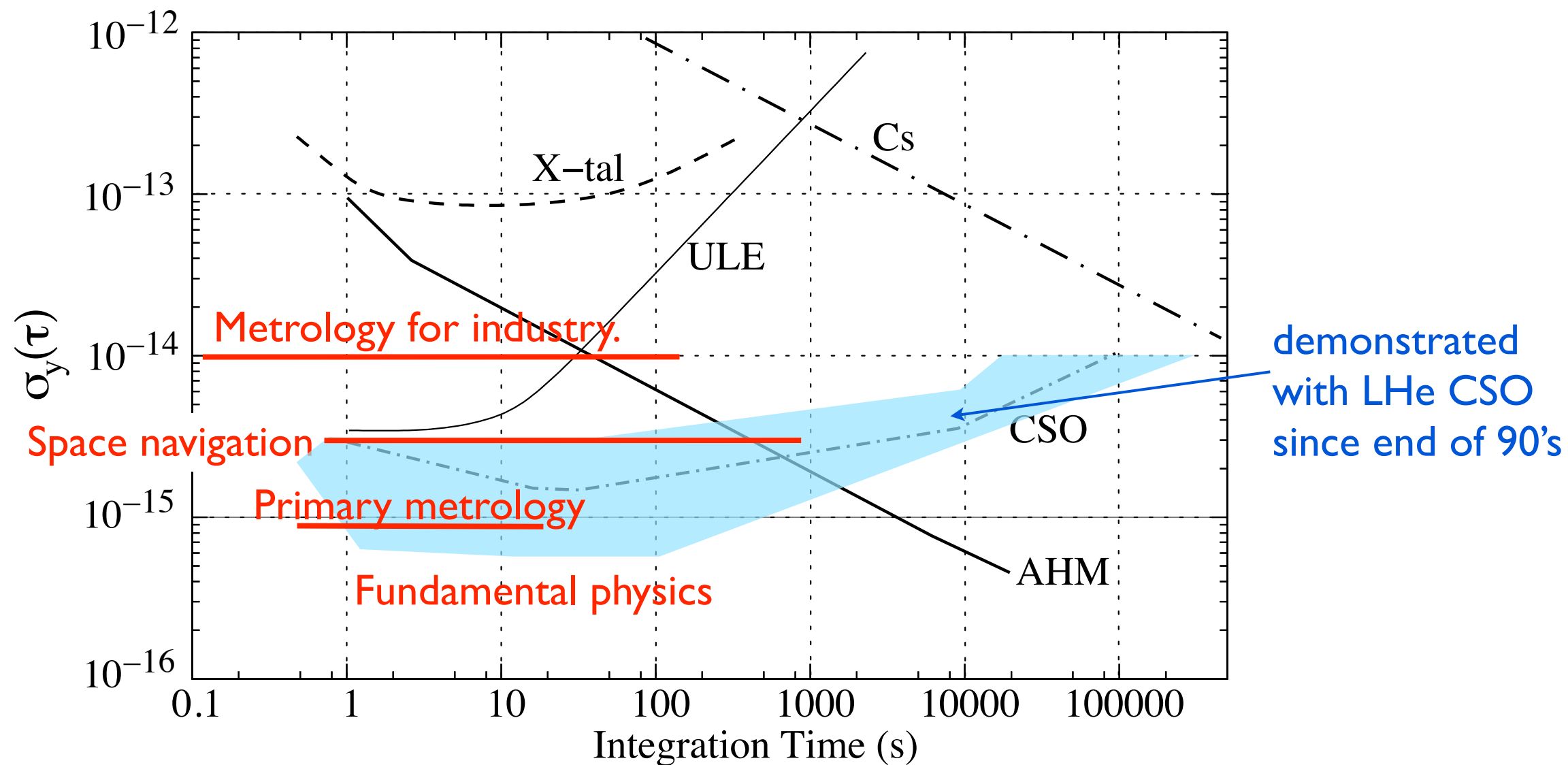
- Review of the CSO at Femto-ST
- The ELISA project
- The ULISS project
- ULISS validation and preliminary tests



The ULISS project is funded by:



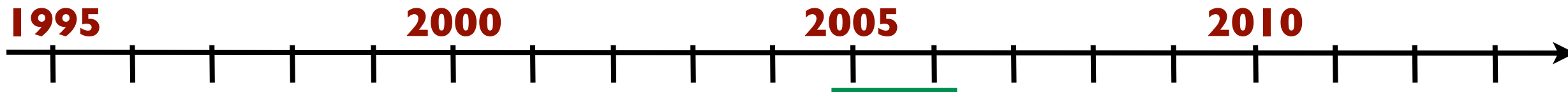
Need for high short-term stability



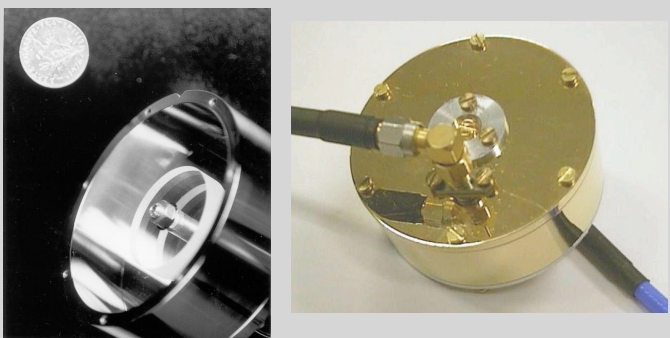
Some applications in remote sites (Deep Space Network Antenna)

Challenge: reliable cryogenerator – let alone the L-He bath

Cryogenic sapphire oscillator at FEMTO-ST



Room T and 77K

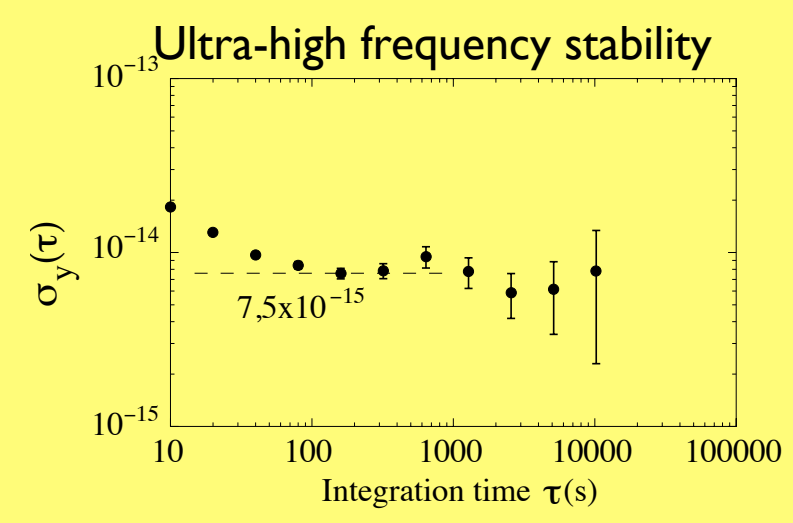


Low phase noise Osc.
5 GHz, 10 GHz, 26 GHz

Thermal stabilisation

Thermal compensation
(dielectric thin films
deposition)

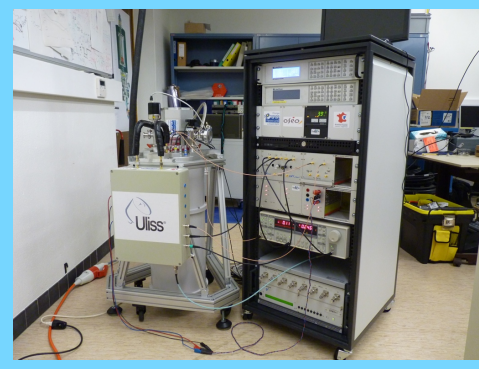
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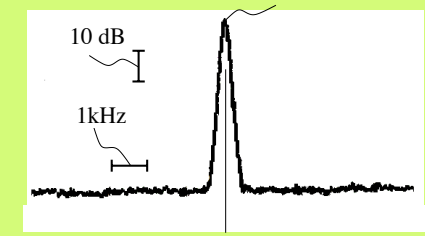
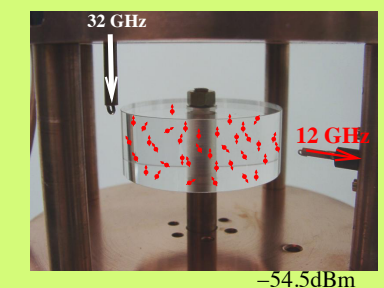
ELISA project



ULISS Project
A new CSO in a
small van to visit
Europe



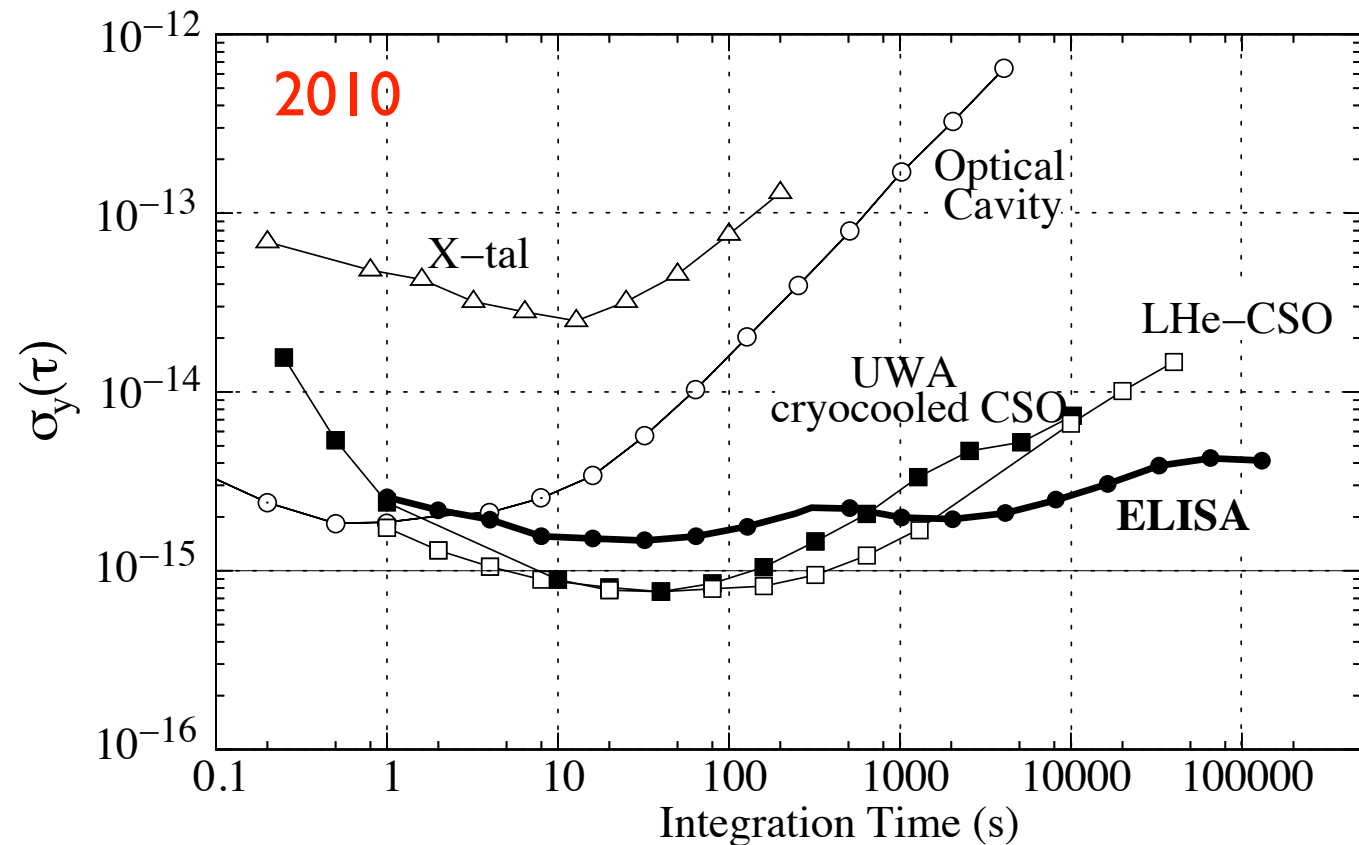
Fe3+ maser effect in WG mode sapphire resonator



ELISA project – CSO for the European Space Agency

Target 3×10^{-15} ADEV $1s < t < 1000s$, without LHe bath

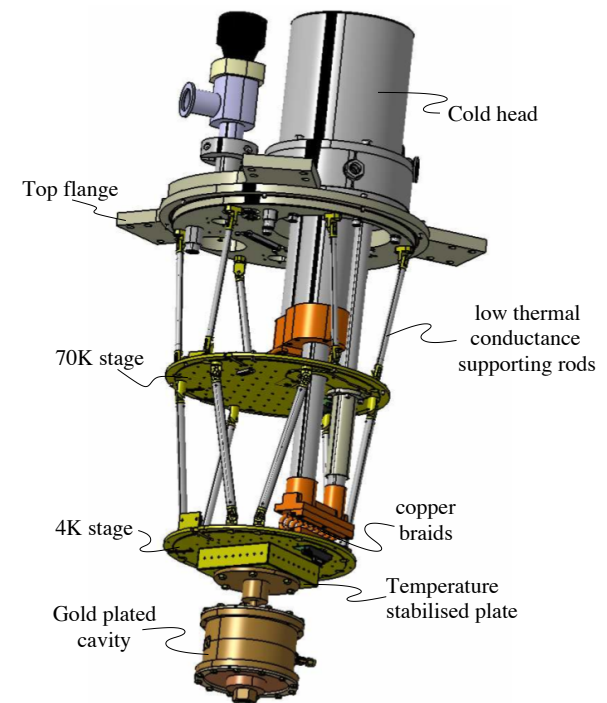
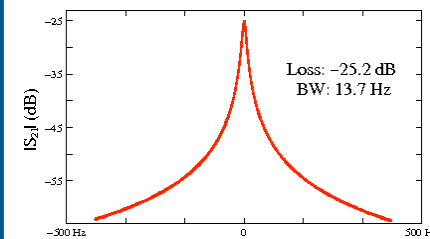
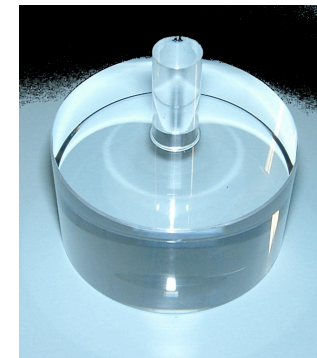
- Specially designed PT Cryocooler
- 10 GHz Resonator design (to avoid complex synthesis)



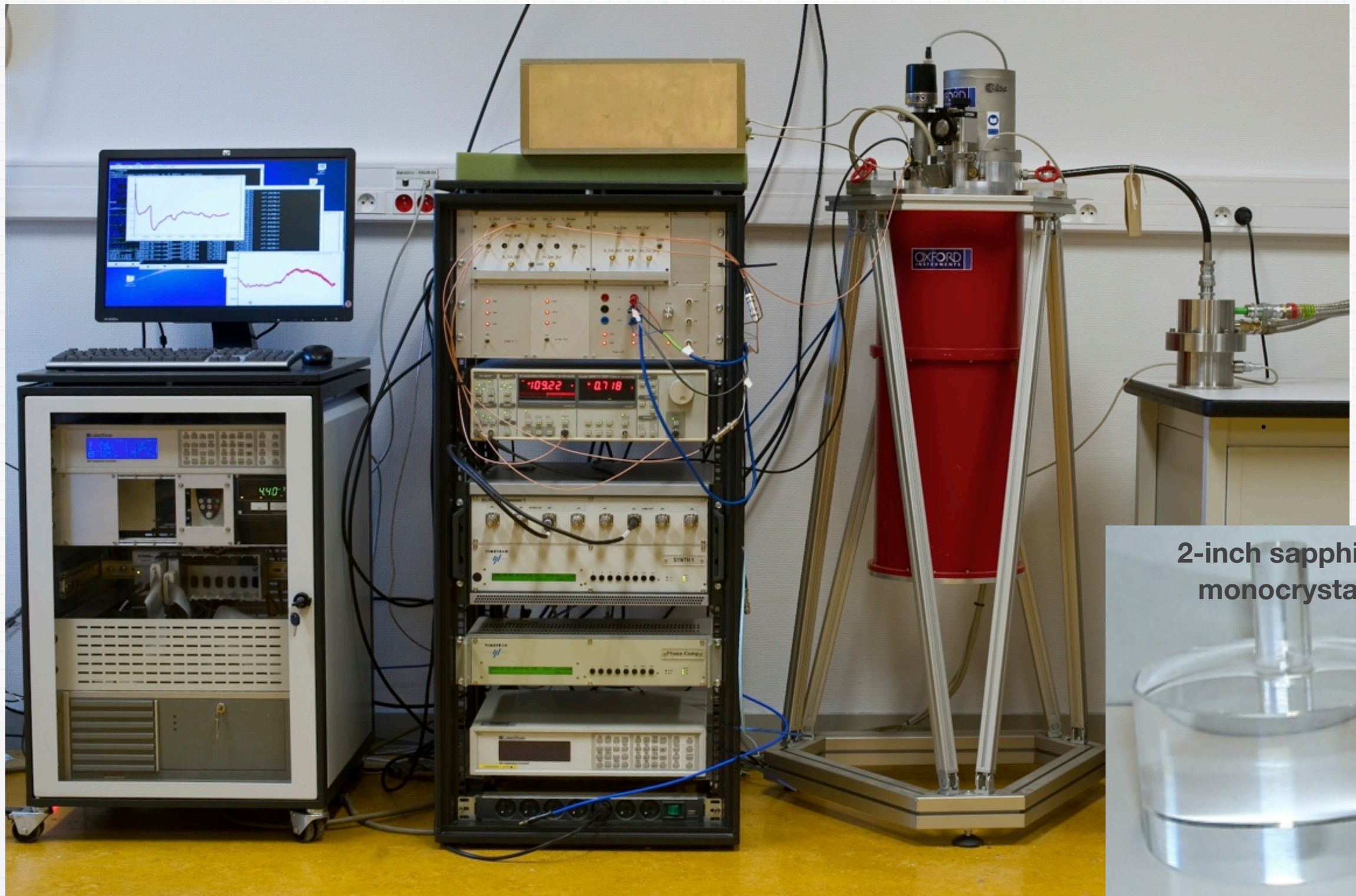
Demonstration of a reliable CSO suitable to remote-site installation

S. Grop et al., Rev. Sci. Instr. 81, 025102 (2010)

S. Grop et al., Electronics Lett., 46(6) p.420–422, 8 March 2010



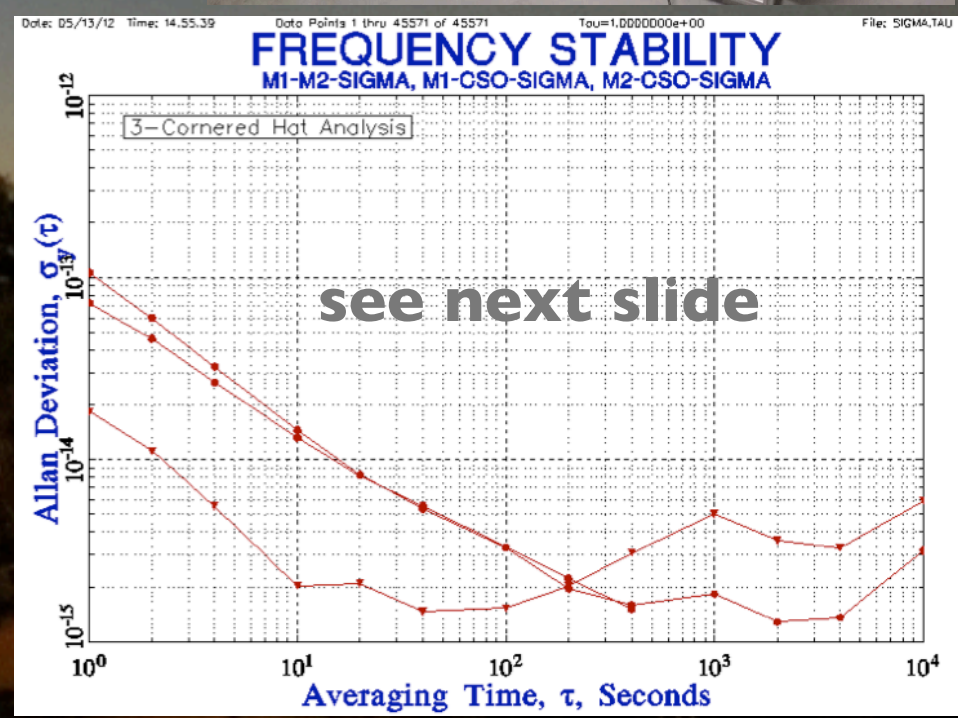
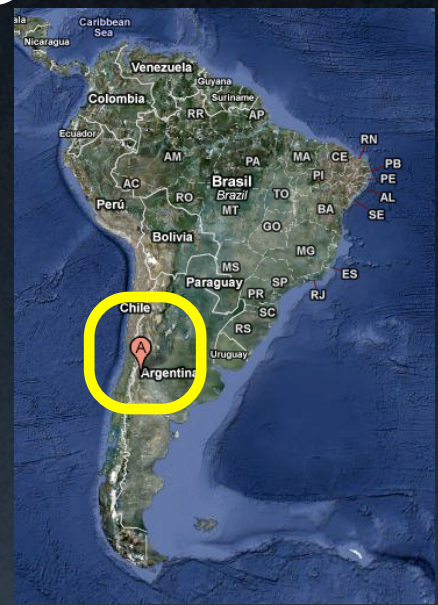
Elisa, before moving to Argentina



2-inch sapphire
monocrystal

ELISA in Malargüe, Argentina

April 2012



Elisa frequency stability

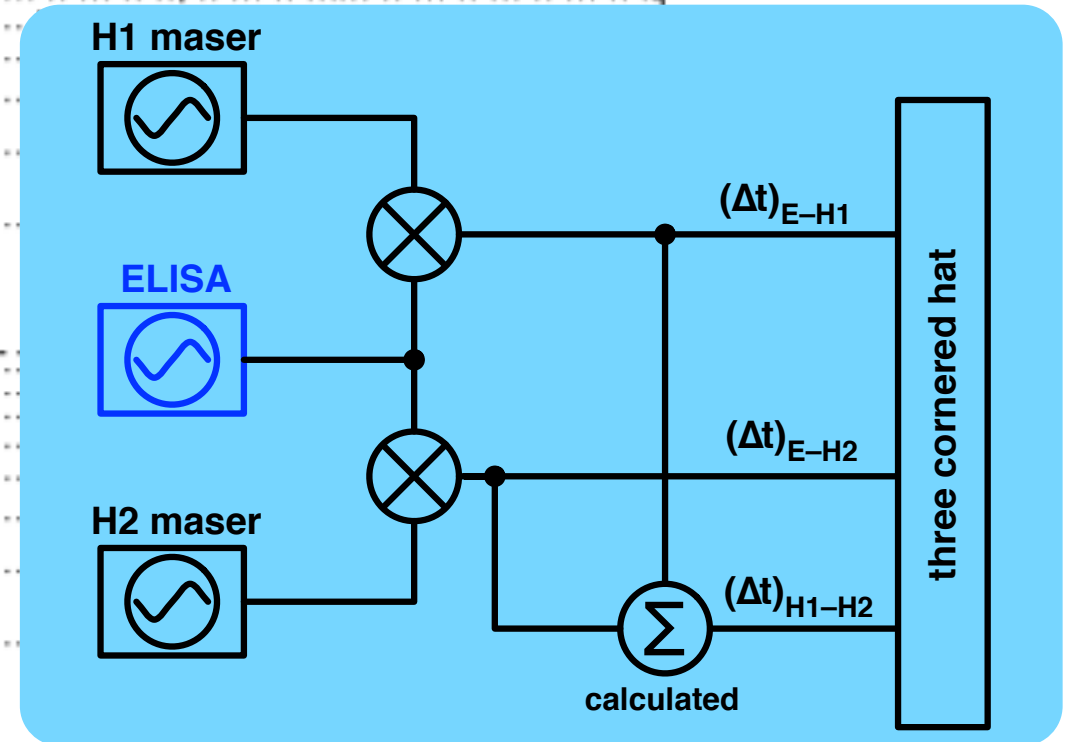
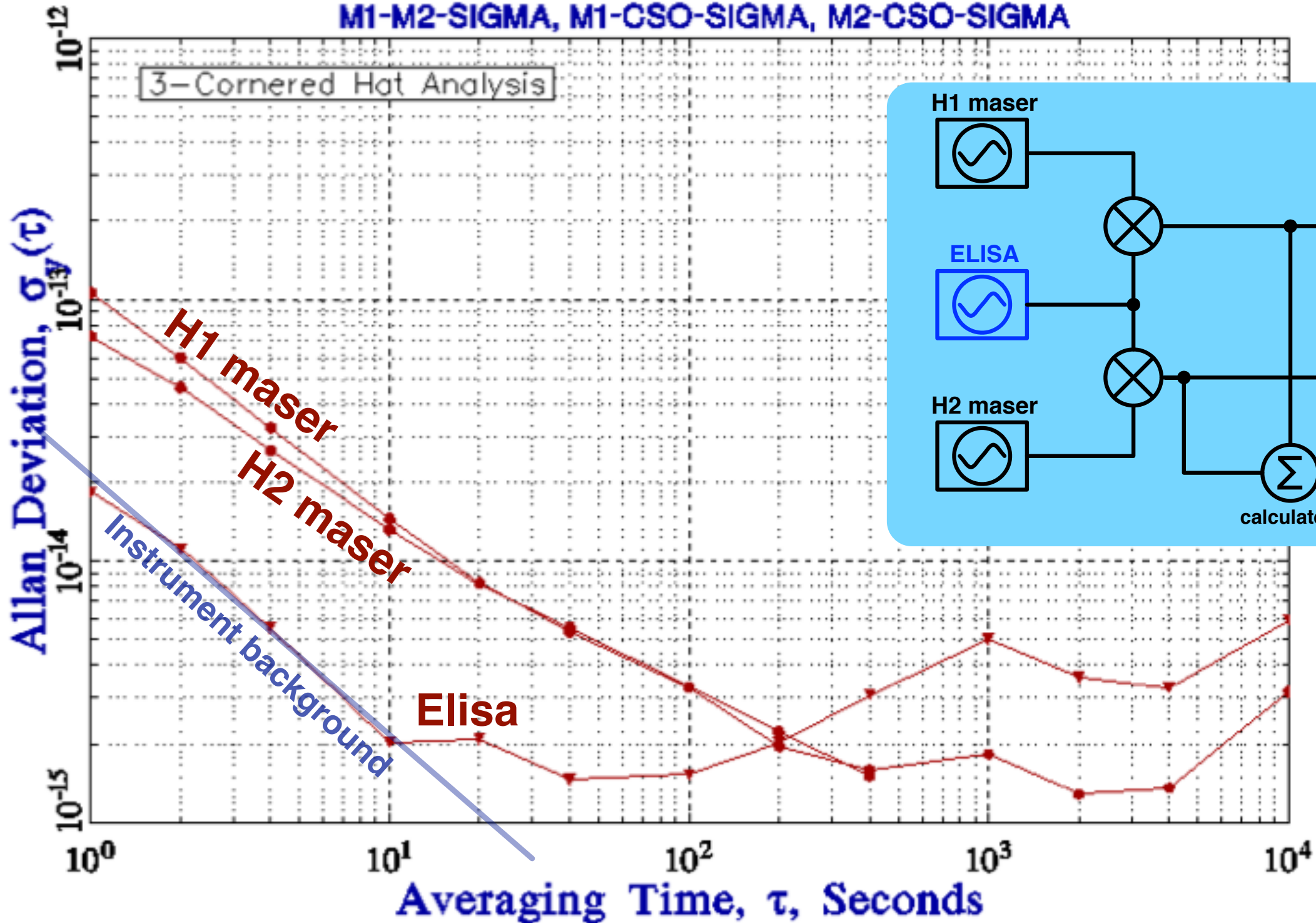
Date: 05/13/12 Time: 14.55.39

Data Points 1 thru 45571 of 45571

Tau=1.0000000e+00

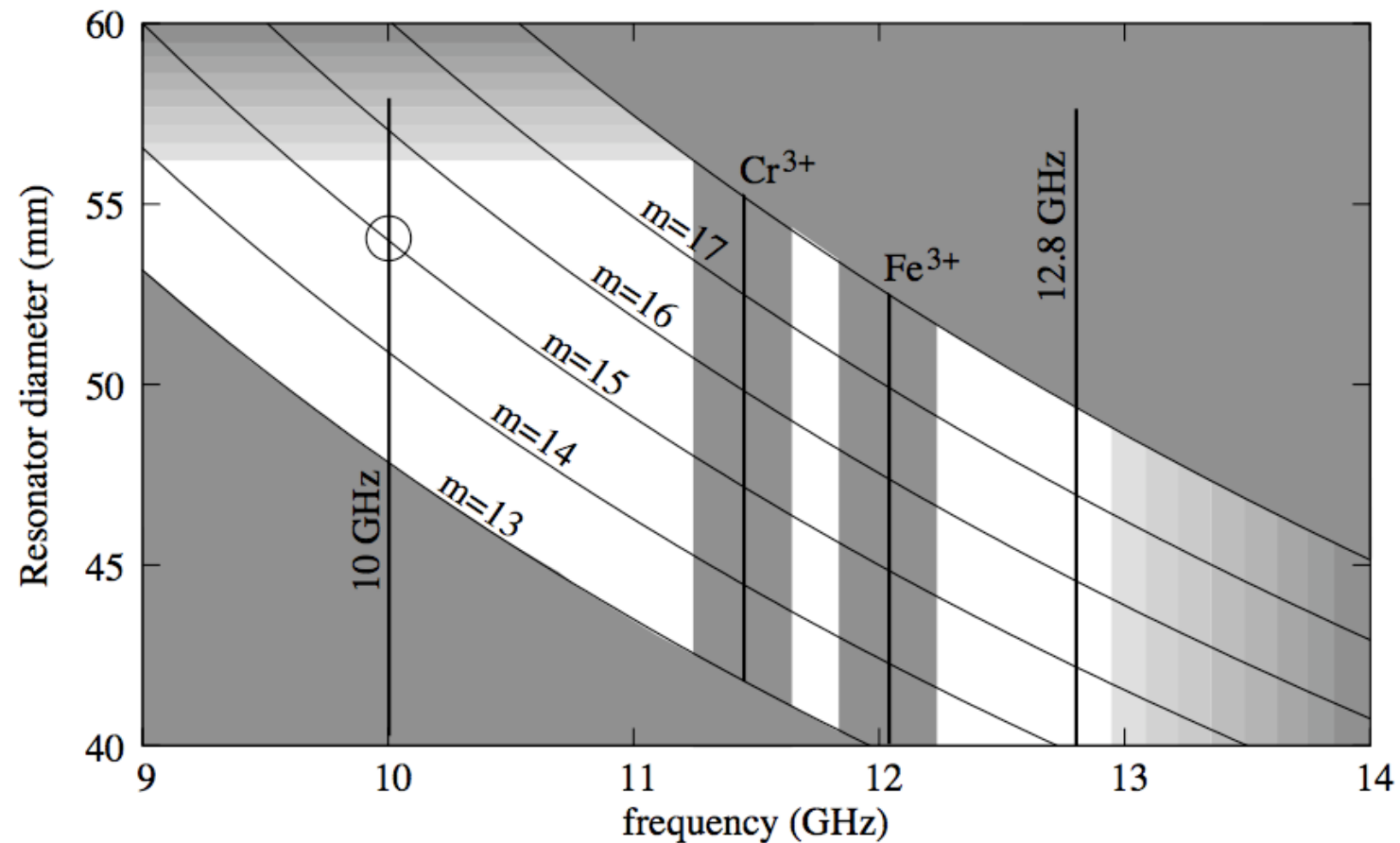
File: SIGMA.TAU

FREQUENCY STABILITY M1-M2-SIGMA, M1-CSO-SIGMA, M2-CSO-SIGMA



Defective air conditioning system, 2 K_{pp} over 1 hour

Resonator design – mode and frequency

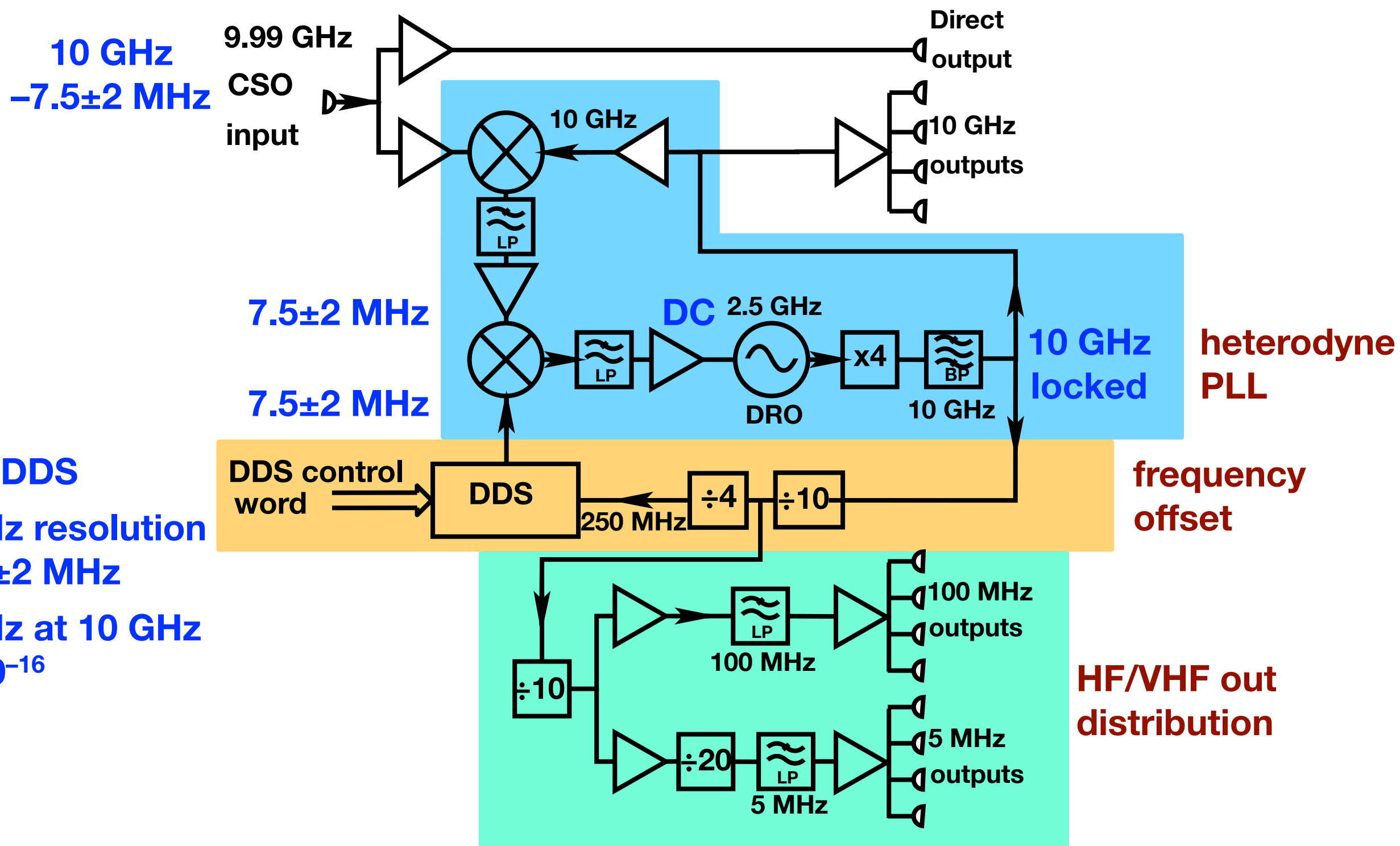


Round frequency (10 GHz) too tough

Our approach: 10 GHz – 7.5 MHz ± 2 MHz
offset mech. tolerances → DDS

- **Oversimplify the synthesizer**
- **Over-specify the synthesizer, thanks to favorable frequency-leverage**
 - **Ready for better-than-expected resonator**
- **Fully reproducible machine**

Frequency synthesis

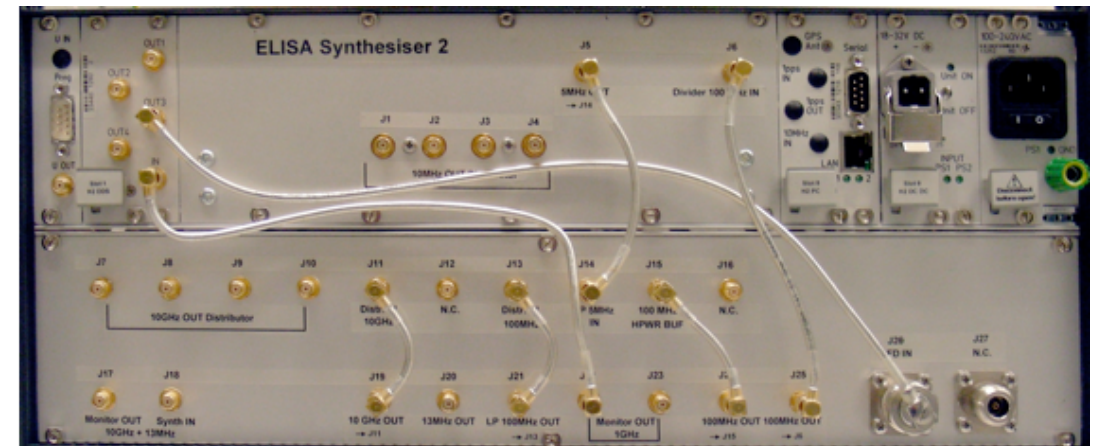
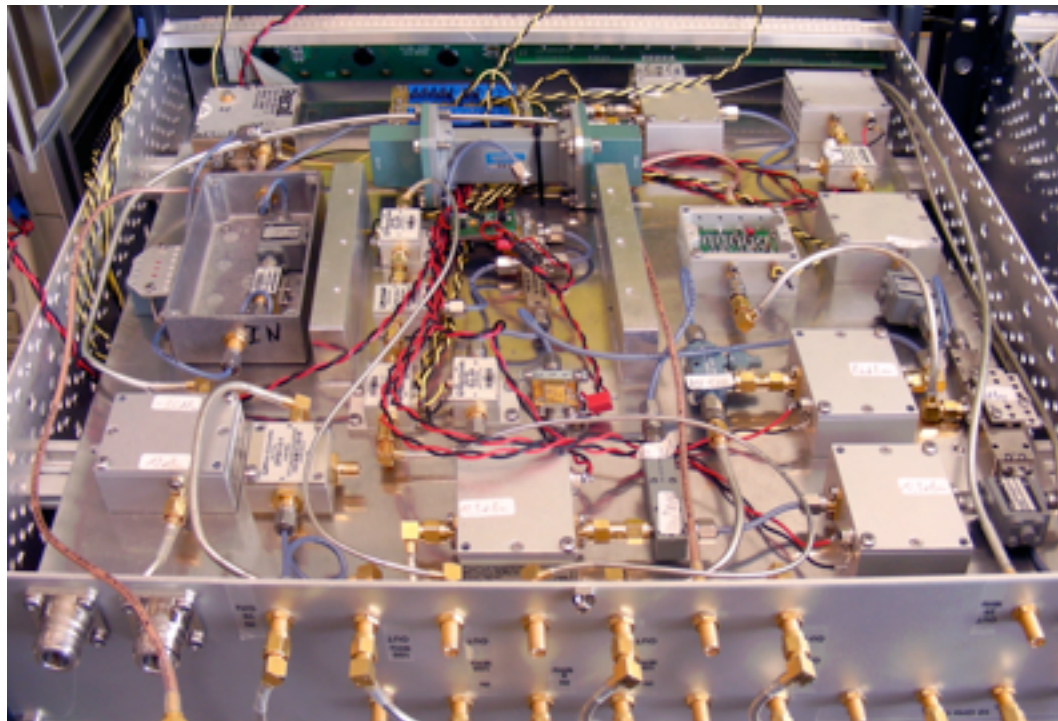
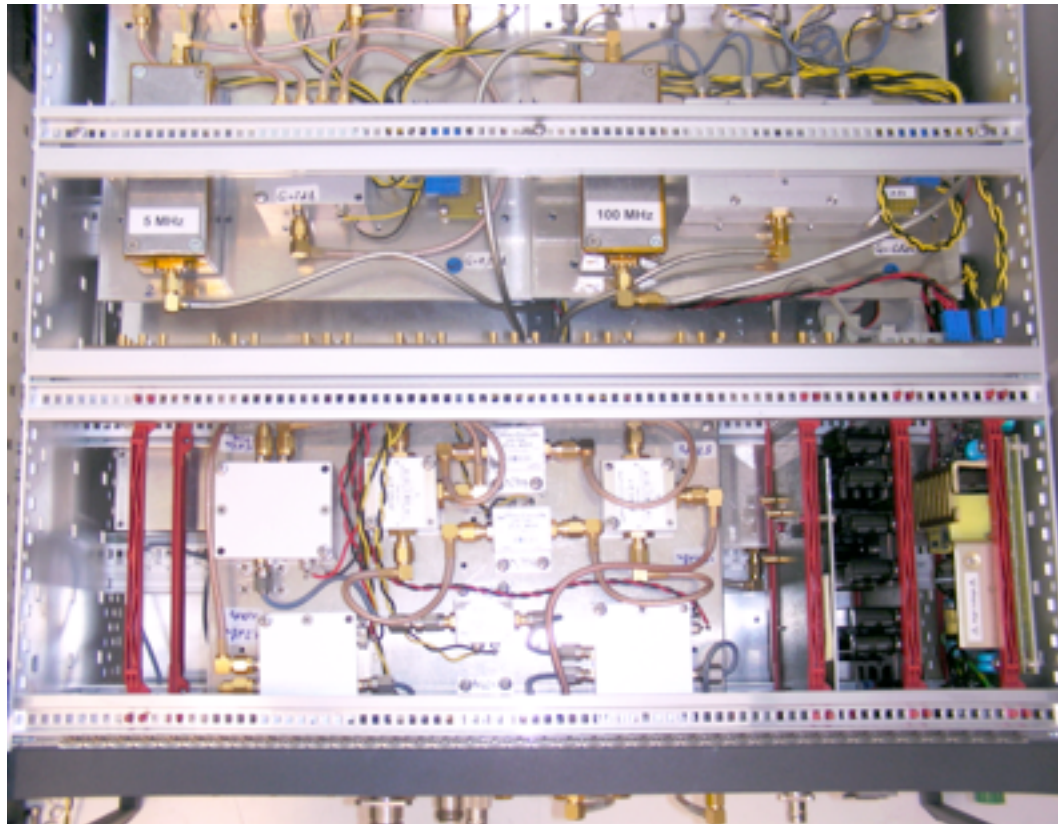


48 bit DDS

0.9 μHz resolution
at 7.5±2 MHz

3.6 μHz at 10 GHz

3.6×10^{-16}



Potential users

- Space agencies
- VLBI observatories
- Metrological Centers
- Research Labs
- T&F Industry

**CSO was complex,
difficult to use
outside a lab**

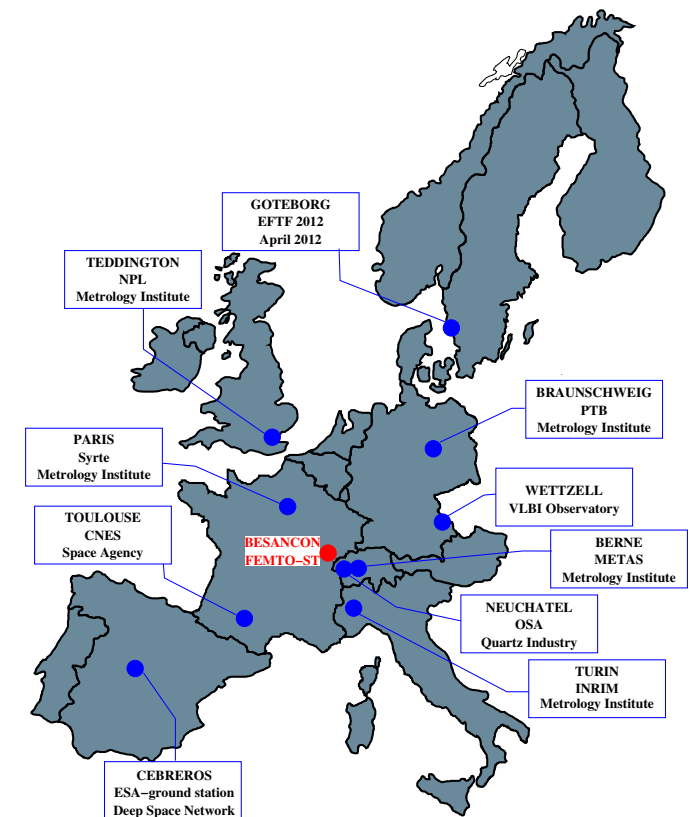
**ELISA demonstrates
an autonomous CSO
state-of-the-art ADEV
without LHe bath**

ULISS project

- Develop a new cryocooled oscillator specially designed to be transportable.
- Testing it in the potential user's sites through Europe.
- Create a business unit ULISS (managed by Univ. FC)



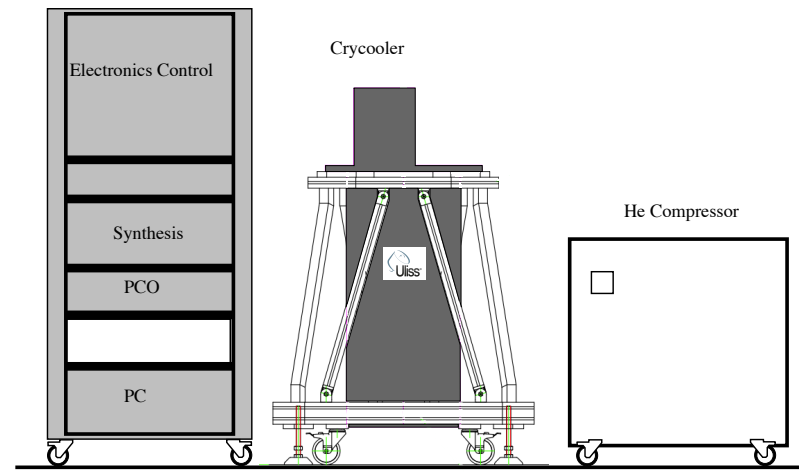
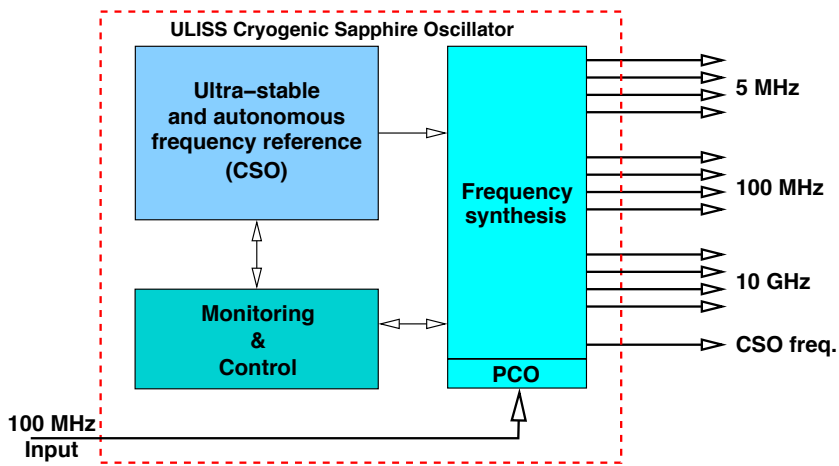
www.uliss-st.com



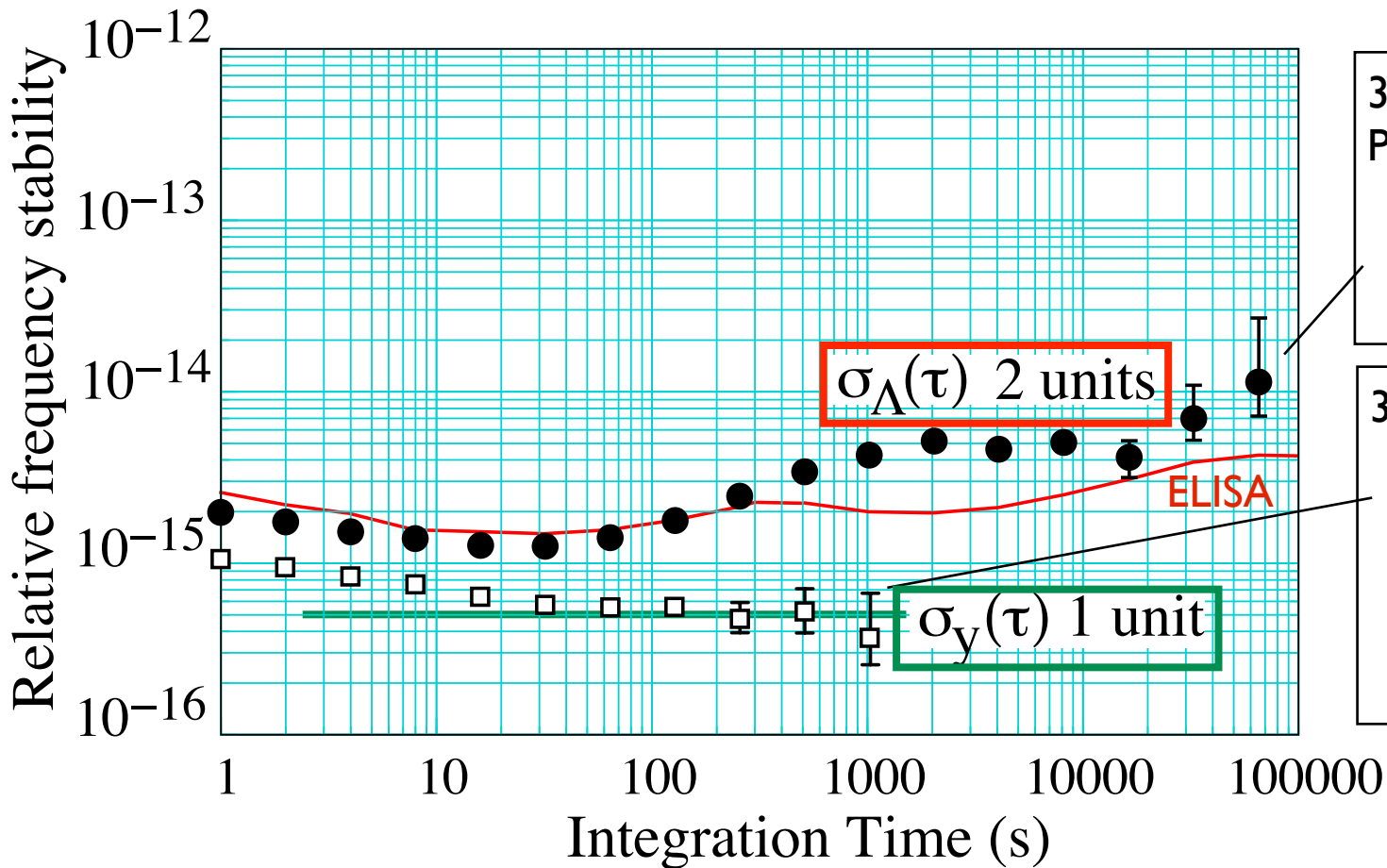
Since April 2012:

- ULISS was build and validated
- Two sites already visited (Neuchâtel and Toulouse)
- ULISS was in Goteborg (EFTF 2012)
- ELISA installation in Malargue

ULISS CSO



ADEV measurement ELISA/ULISS



3 days measurement without post-processing
 Perturbed environment:

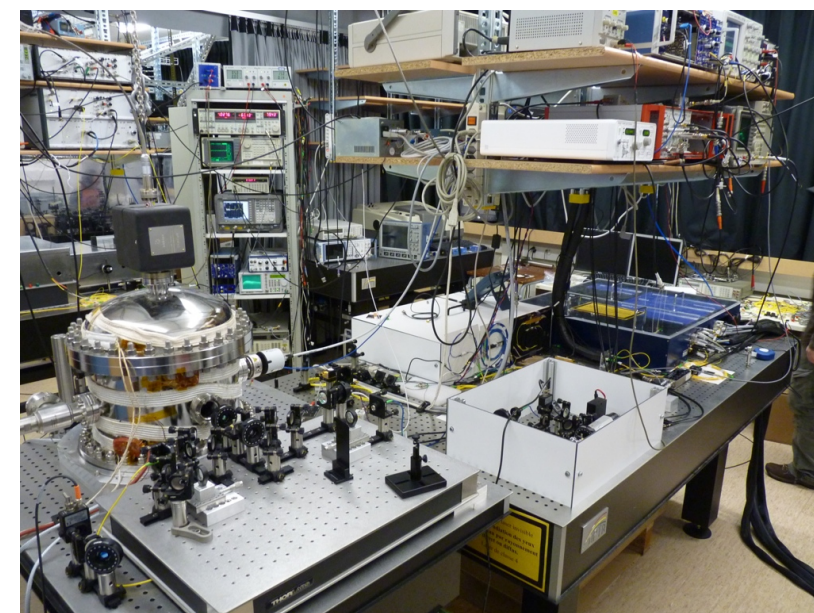
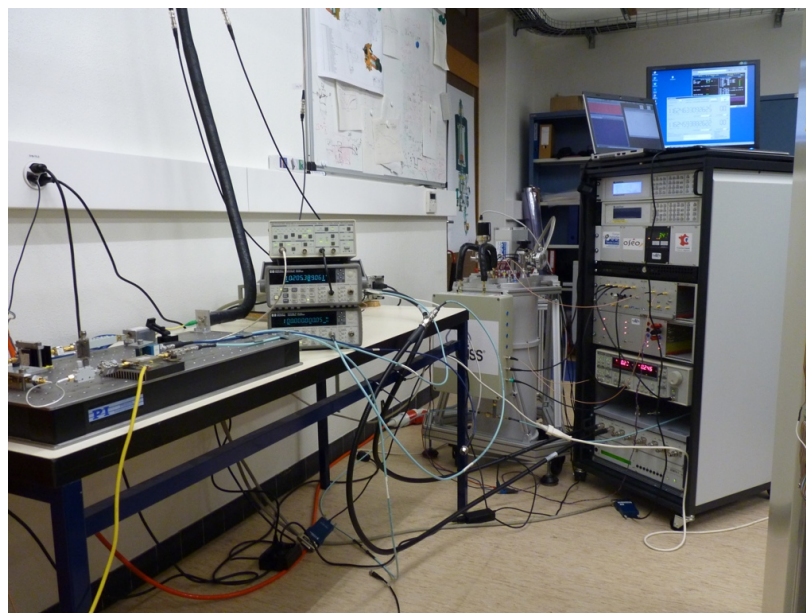
- Technical university (ENSMM), ≥ 800 students
- Air conditioning still not operational during measurements

3 hours extracted from the entire data set

- Quiet environment, nighttime
- Take away 3dB for two equal units
- Λ -counter compensated: for flicker: $\sigma_{\Lambda}(\tau) \approx 1.3 \times \sigma_y(\tau)$

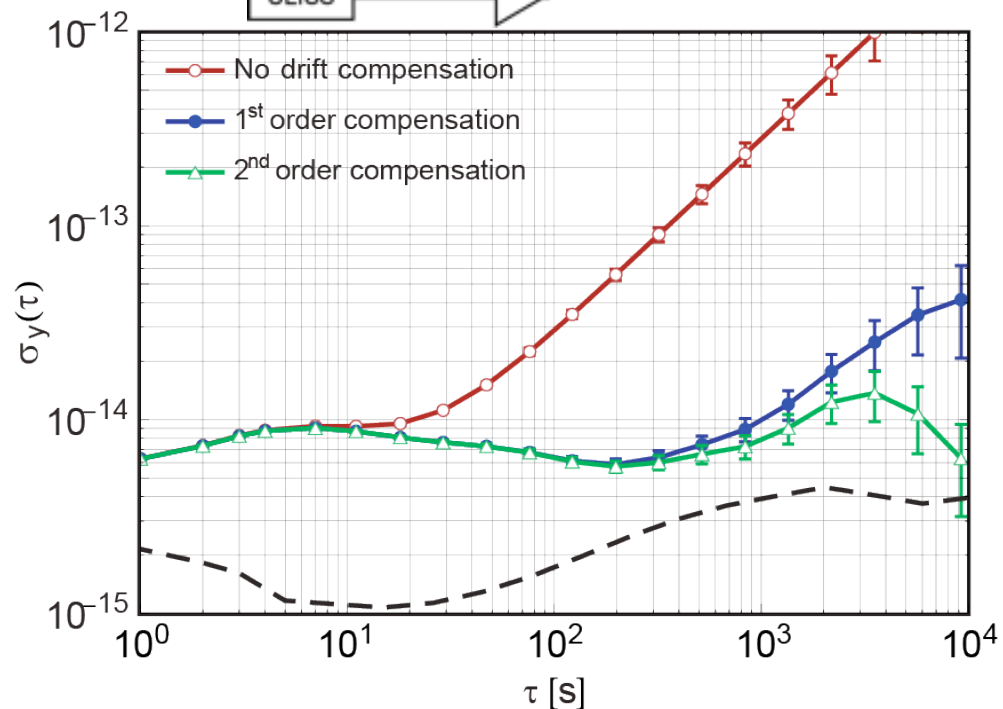
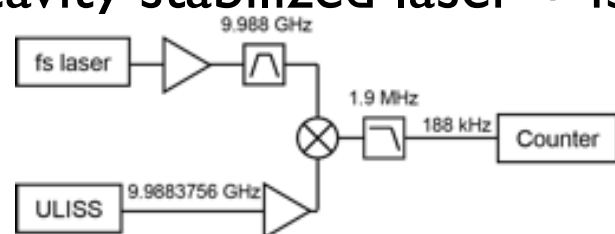
flicker floor: 4×10^{-16} $10 \text{ s} < \tau < 1,000 \text{ s}$

ULISS in Neuchâtel (LTF) - Feb 2012 -

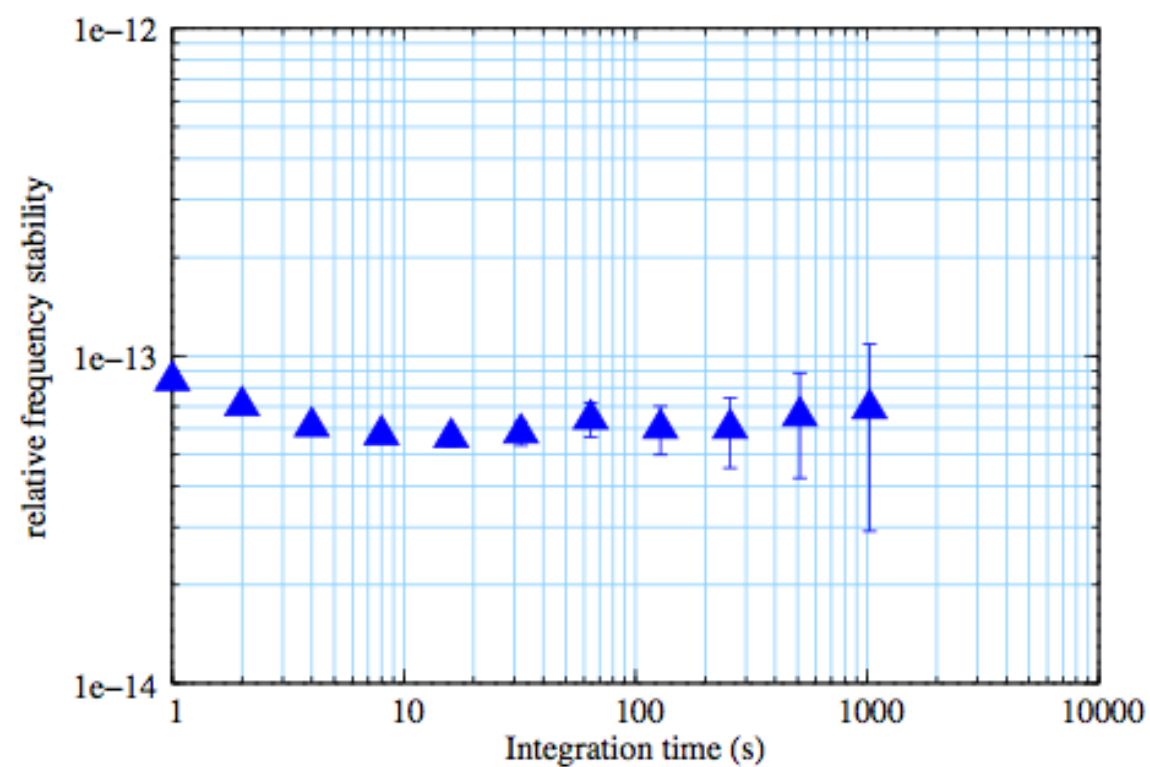


After 36h warm-up (actually, cooling down)

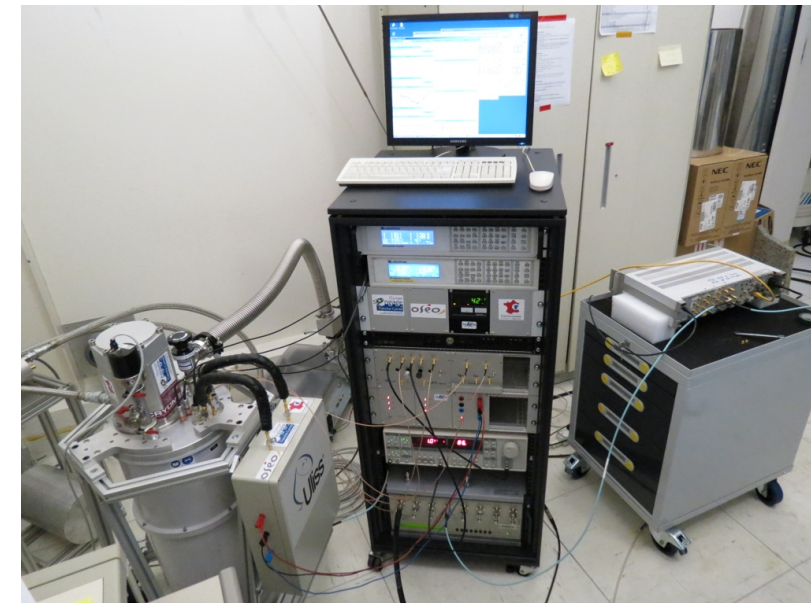
Test photonic generation of μ -wave:
ULE-cavity stabilized laser + fs



5 MHz OCXO from OSA

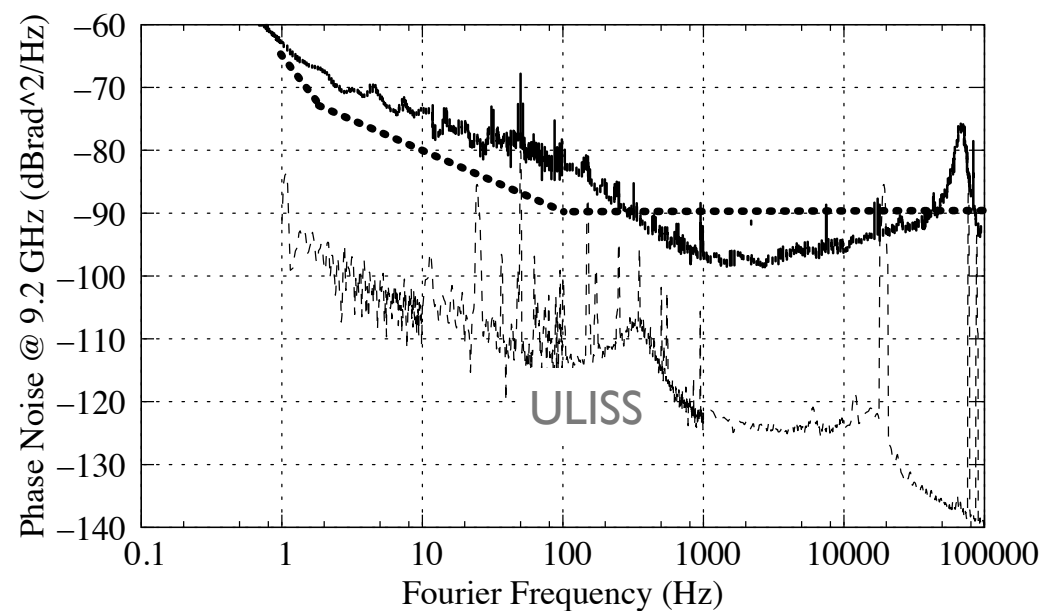


ULISS at CNES, Toulouse, April 2012

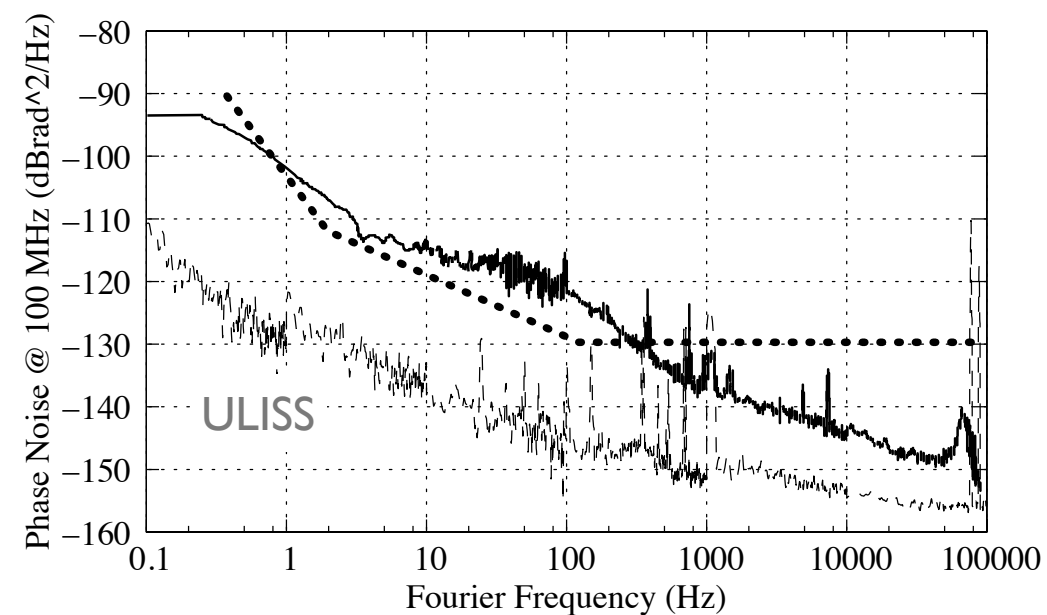


Validate the flight prototype of the PHARAO synthesizer

9.192 GHz Phase noise

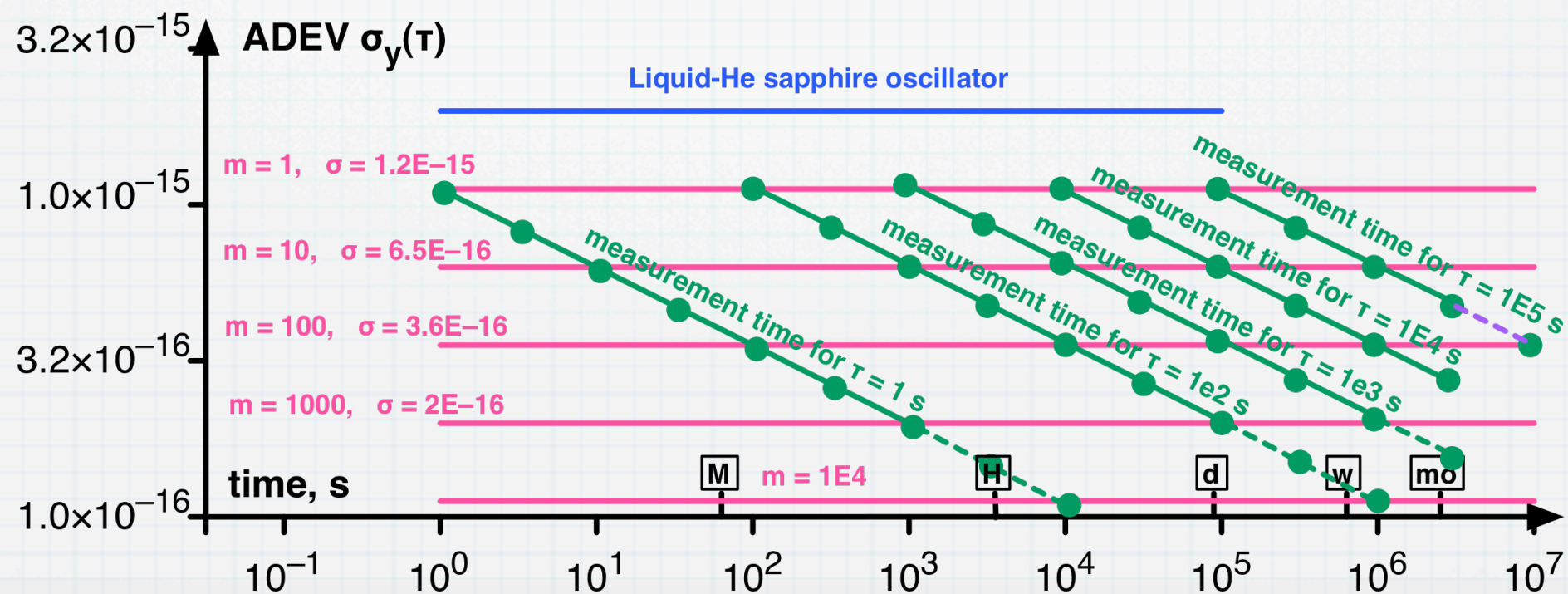
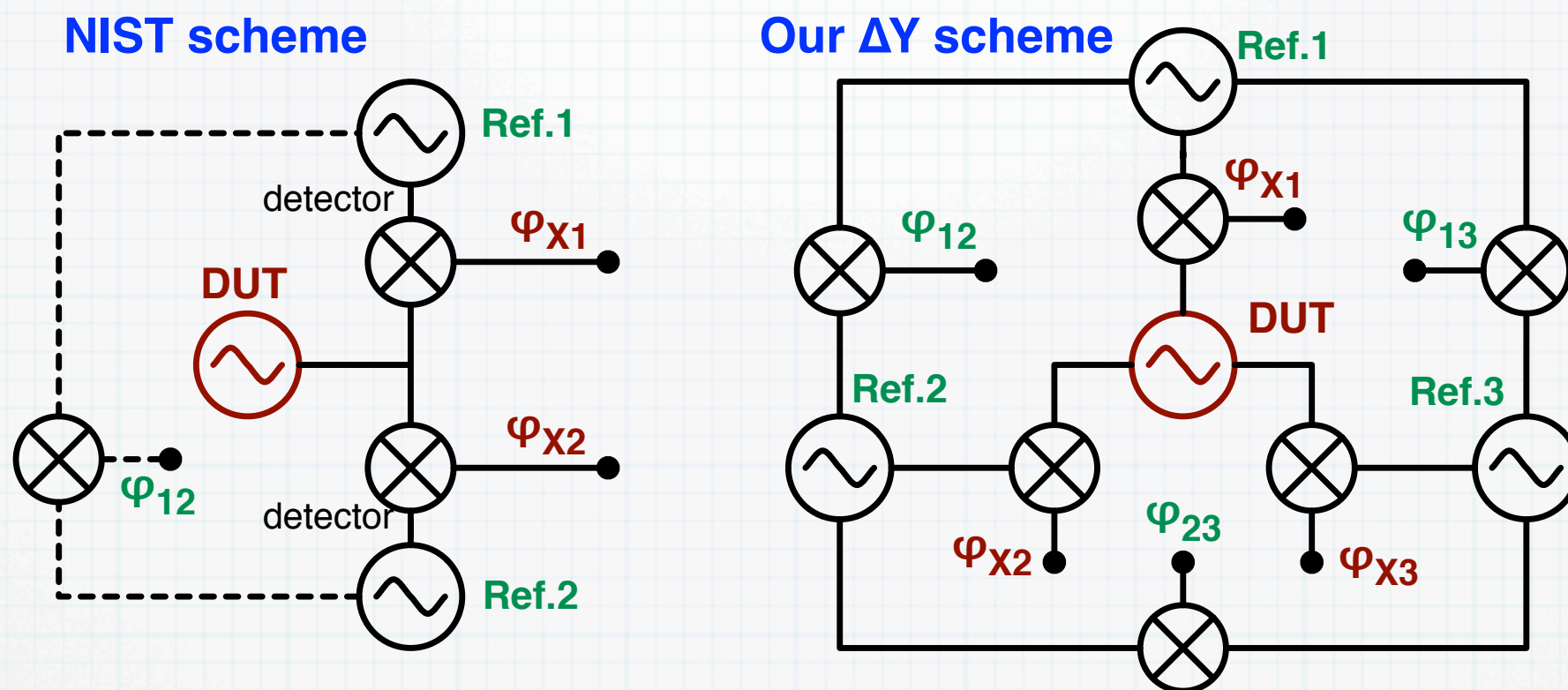


100 MHz Phase Noise



Coming soon – three sapphire oscillators

Planned full measurement of $S\phi(f)$ and $\sigma(\tau)$ of Uliss before and after traveling



SUMMARY

Already demonstrated

- 👉 **state-of-the-art short term stability**
- 👉 **reliability and reproducibility**
- 👉 **suitability to remote sites / difficult logistics**
- 👉 **metrology applications**

Some people believe that

“cryogenic sapphire is more about a lab experiment than a reliable machine”

This is definitely not true

The ULISS Odyssey will continue

New travels planned soon

Suggestions are welcome

<http://uliss-st.com>