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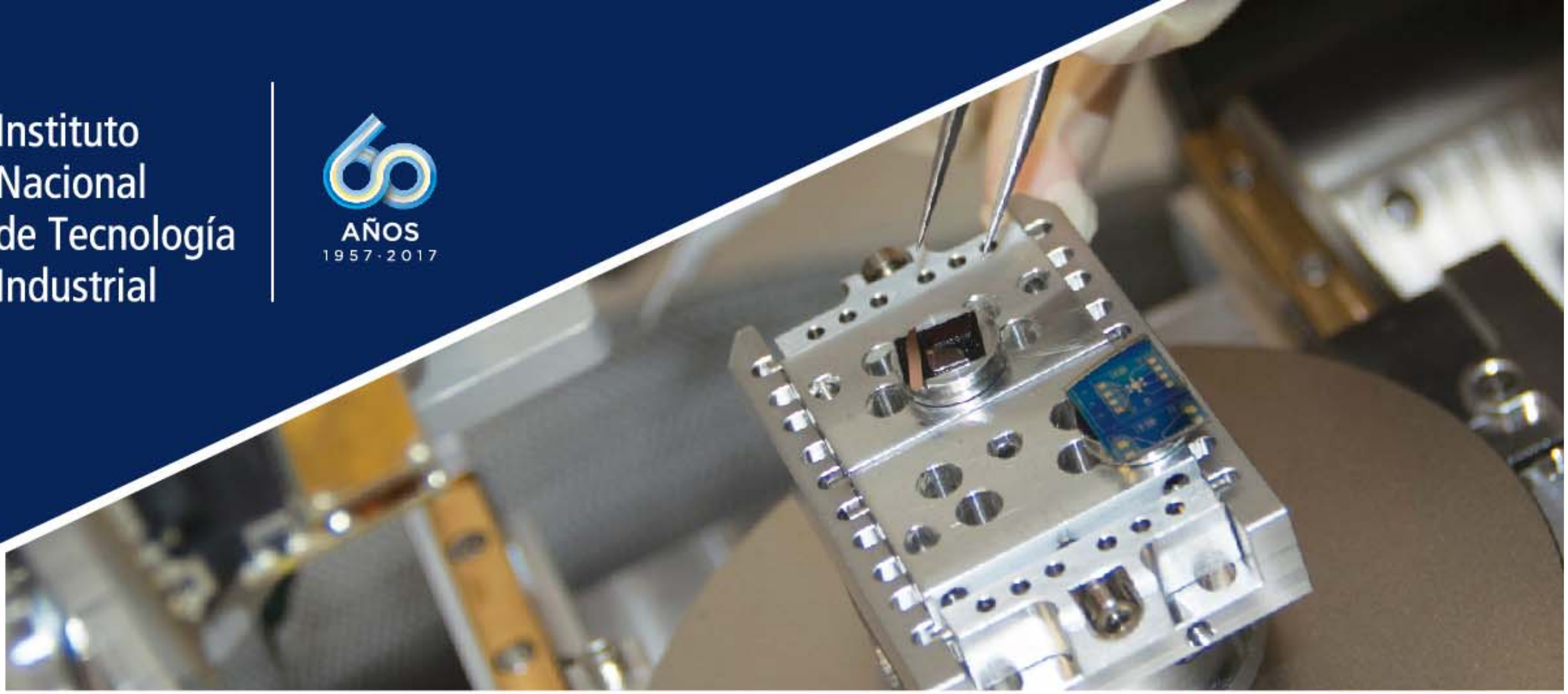
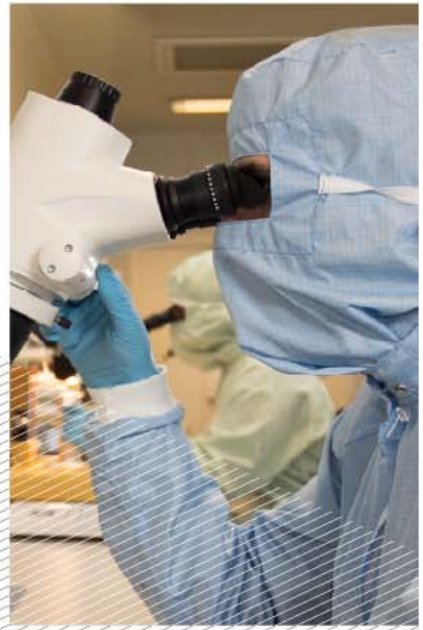


Quantum Metrology at INTI



HECTOR LAIZ
BIPM, Sevres
Octubre, 2017

Ministerio de Producción
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Metrology applications of QHE - Quantum conductors

Electrical conductance of a channel

$$G_{el} = \nu \frac{e^2}{h}$$

Geometry and material independent

Particle dependent

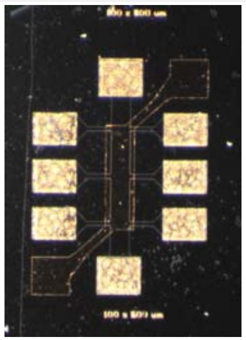
Thermal conductance of a channel

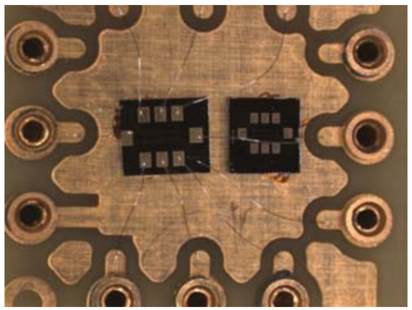
$$G_{termica} = \frac{\pi^2 k_B^{\ 2}}{3h} T$$

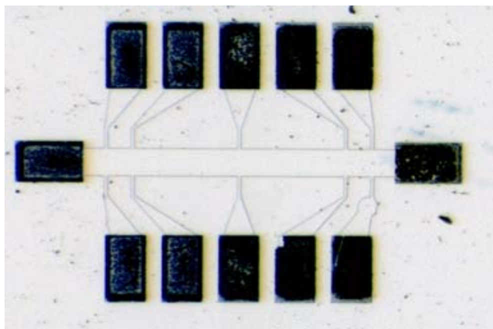
Universal to all known particles

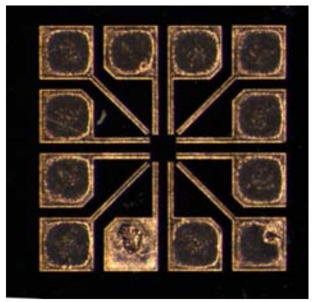
Jezouin, et al. Quantum limit of heat flow across a single electronic channel. *Science*, *2013*

INTI samples production





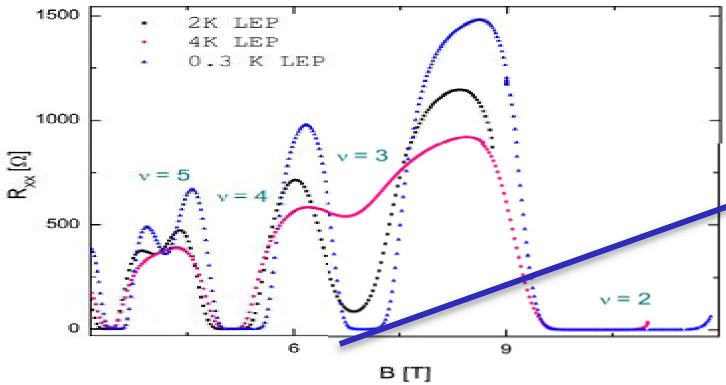




Substrates kindly provided by PTB

Quantum Hall effect under Corbino structures

- To explore thermoelectric properties in GaAs at QHE regimes.
- Experimental measurement of thermoelectric coefficients, possible aplications in temperature standards.



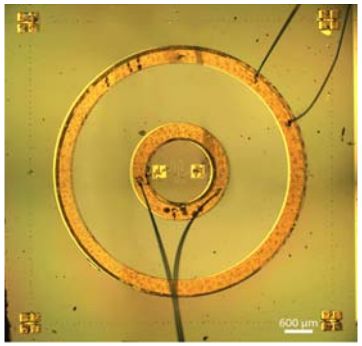
SdH oscillations

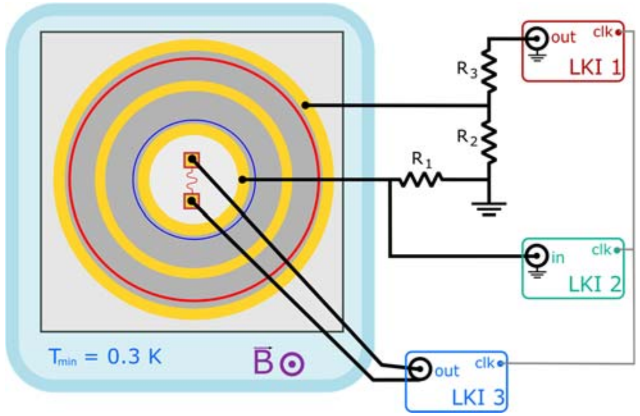
One could use this change as a temperature sensor $\rho_{xx} \sim e^{-\Delta/kBT}$

Corbino

Thermal voltage perpendicular to the heat flow in the QHE regime

Kobayakawa et al. Diffusion Thermopower of Quantum Hall States Measured in Corbino Geometry. 2013 *http://dx.doi.org/10.7566/JPSJ.82.053702*

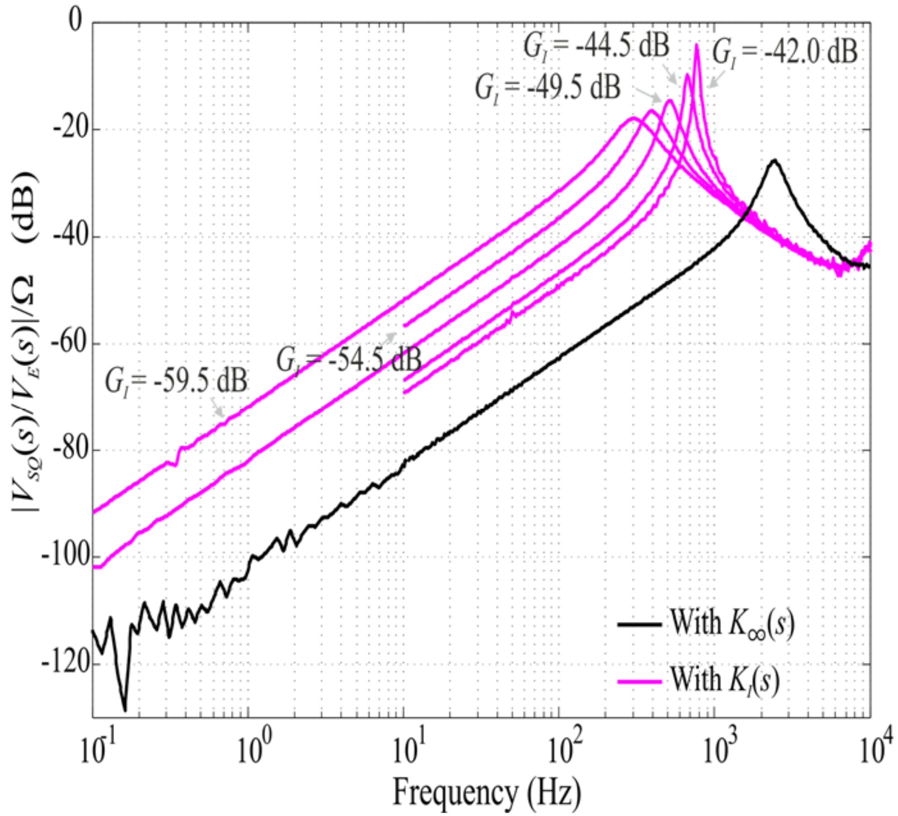




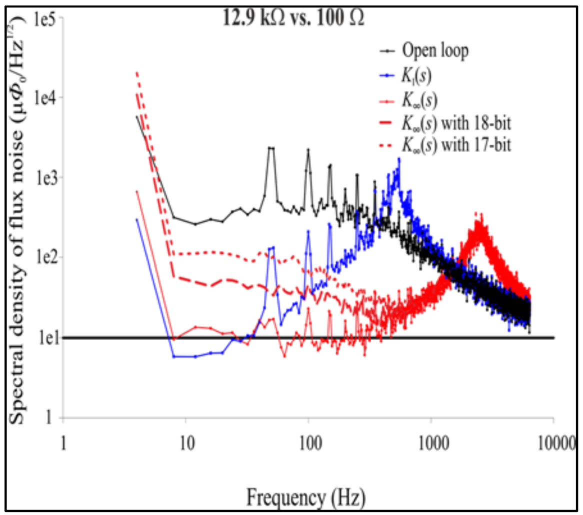
Substrates kindly provided by the Max Plank Institute-Stuttgart.

Robust control theory applied in CCCs

Benefits
1) Model measurement systems
2) Guarantee the bridge stability
3) Increase the system bandwidth
In DC measurement, this allows faster current reversals
4) Improve the signal to noise ratio
5) Reduce the effect of distortion that can increase the std deviation or saturate the detector



The transfer function of a CCC was improved with robust control



The detector output noise was reduced

Waveform metrology based on spectrally pure Josephson voltages – (EMPIR-QuADC)

QuADC WP1: Overview of System: Quantum Voltage Digitiser

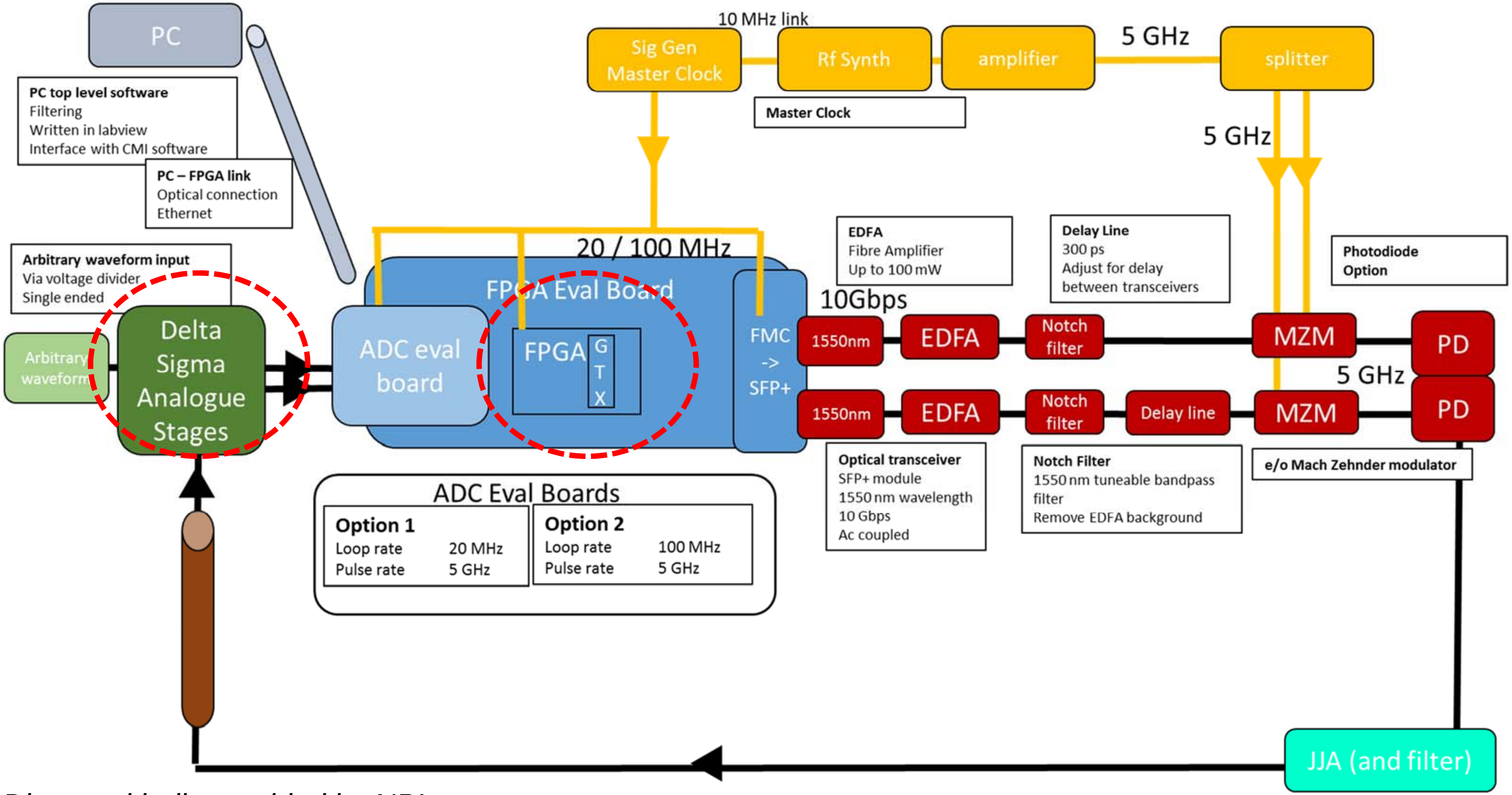


Diagram kindly provided by NPL

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Towards a Quantum Sampling System

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PTB Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

Abstract

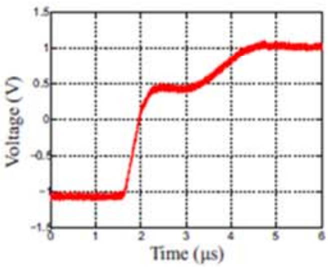
This poster describes the development of a system based on the Josephson effect, to calibrate and characterize voltage standards and digital sampling systems.
In particular, this work includes the test of a digital-to-analog converter as a source to bias the segments of the programmable Josephson array.

The 1 V programmable array, built at PTB, has 8192 SNS Josephson junctions divided into 14 binary segments.

First PJVS results

Agreement between the PJVS and the conventional JVS of 85 ± 100 nV/V was found in the calibration of a zener standard at 1.018 V. In addition, thermal voltages lower than 30 nV were measured.

Signal transients were studied in order to establish the frequency limit. A single current source, based on the AD5791, was applied to the full array in order to produce a 2 V peak-to-peak change. The step transients have been observed and measured using a digital oscilloscope. A transient of 5 µs was obtained.

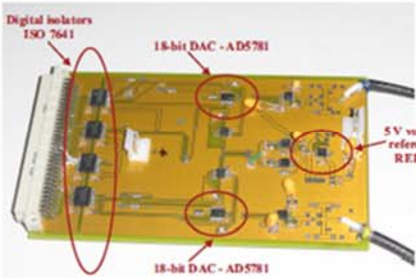


A sampling system based on a 24-bits sigma-delta ADC was calibrated with the PJVS for AC and DC voltages as follows: for AC voltage a square waveform of 100 Hz has been synthesized to obtain the AC correction, δ_{AC}. Then, the amplitude of the square waveform was applied as a DC voltage and a DC correction, δ_{DC}, was calculated with a standard deviation of 8 µV/V. Finally, an AC/DC calibration difference was obtained equal to -1.2 µV/V.

New programmable current source

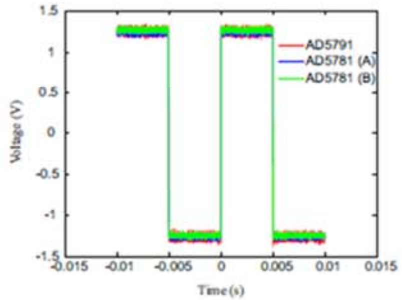
The current sources were constructed connecting 50 ohm resistors in series to the output of programmable voltage sources. These sources can generate DC voltages, square and triangle waveforms using a commercially available R-2R DAC with 18-bit resolution (or 20-bit in the first prototype), 5 V dynamic range and a slew rate of 50 V/s. In this application the sampling frequency was set to 100 kHz. The DAC were controlled by a CPLD running at 66 MHz clock frequency via an isolated serial communication of 121 ns per bit.

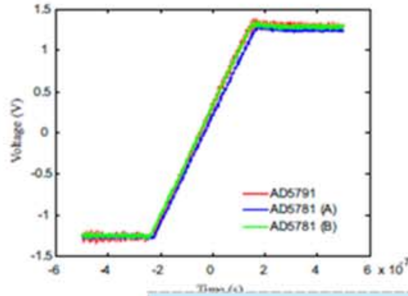
Second source prototype, two DAC were implemented.



Performance of the bias source

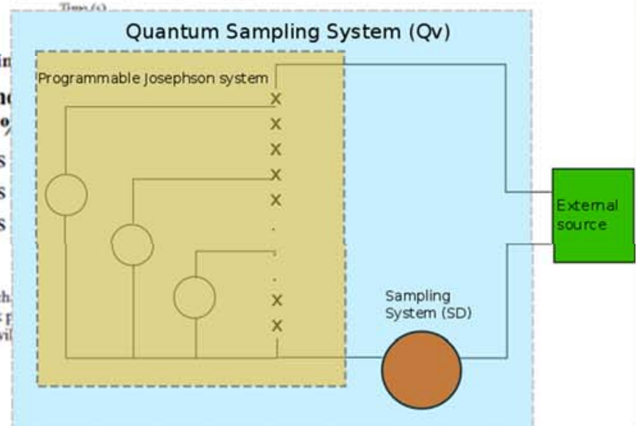
The output voltages of three DACs were measured with a digital oscilloscope using compensated X10 probes. One of this DAC, model AD5791, was implemented in a single board and the others, model AD5781, were implemented on the same board. All the sources were controlled with the same CPLD (and serial clock) in order to generate synchronized square outputs.
The output synchronization during positive and negative slopes were studied. Delays between channels lower than 25ns were found. In addition, the measured rise times were in good agreement with the DAC specifications.





The following table summarizes the measured values. The RMS Noise was lin

DAC	Resolution	Rise time (10%-90%)	Fall tim (90%-10%
Ad5791	20-bits	296 ns	312 ns
AD5781 (A)	18-bits	311 ns	335 ns
AD5781 (B)	18-bits	299 ns	332 ns



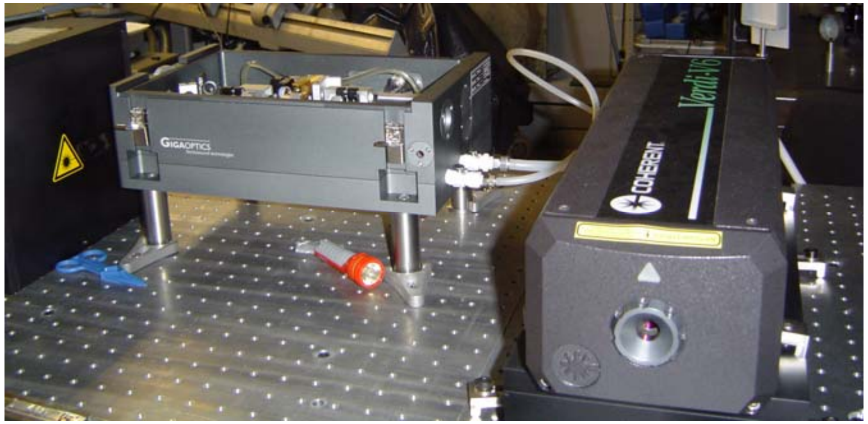
Conclusion and Outlook

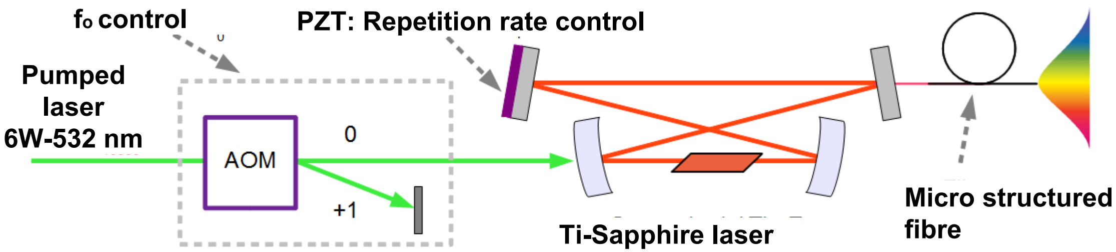
The tests presented in this poster and in the summary paper have fulfilled our expectations. The development is ongoing on a two year schedule. The next step will be to add more channels to the programmable current source in order to use all the segments. These channels will act synchronously and will be controlled with a FPGA in real-time to obtain different signal waveforms, frequencies and amplitudes.

Finally 16 channels will be built, 14 will be used to control the PJVS and two ch available for synchronization purposes. All the board will be connected with a back p meet Eurocard specifications. In addition, communication and power supply wi using high frequency digital isolation and DC-DC isolated converters.

Frequency comb - Optical link

The INTI frequency comb, a pumped laser (a diode laser of solid state) and a Ti-Za cavity, (an oscillator of femtoseconds (GIJAJET 20)) with a pulse repetition rate of 1GHz (± 20 MHz), pulse duration <50 fs.

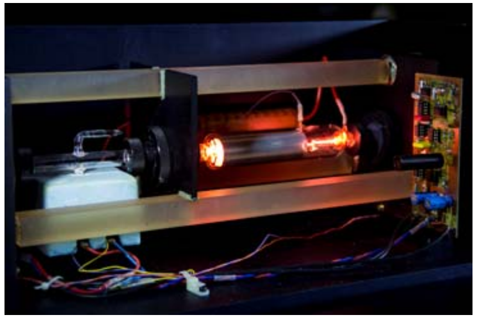




Scheme

The goal

- Link the optical frequency to the Cs frequency
- The meter realization



- Transfer a traceable frequency through an optical link

Strategic Plan 2018-2023

Besides de current projects:

1. **Single photon radiometry (cooperation with the Defense Research Center)**
2. **Optical clock (cooperation with the National University of Buenos Aires)**
3. **Photonic Thermometry**

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Thank you !