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MEASURING ANGLE WITH PICO METER RESOLUTION

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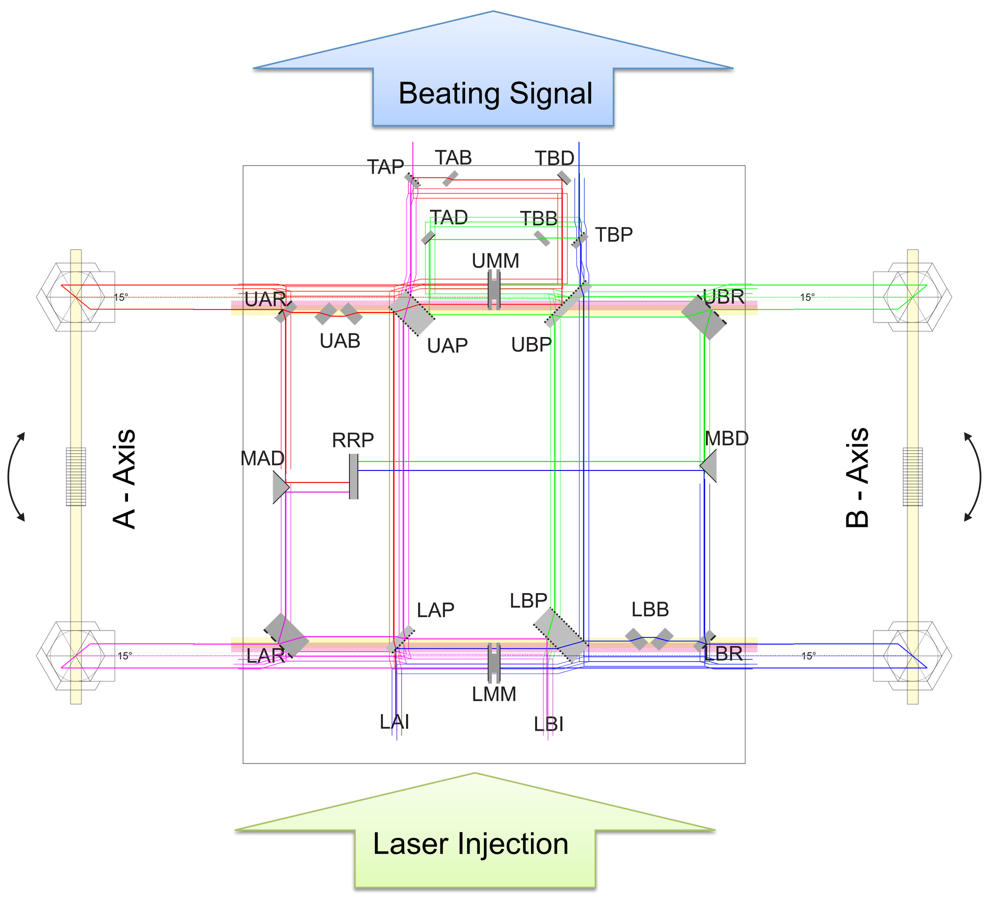
HIGH RESOLUTION γ-RAY SPECTROMETER

Energies of the γ-rays emitted in the decay of the capture state to the ground state of a daughter nucleus after a neutron capture reaction can be measured with extremely high precision via Laue-diffraction. In order to match the high demand in angle measurement accuracy, a new optical interferometer with 10 pico radian resolution, linearity over a total measurement range of 15° and high stability of about 0.1 nrad/hour has been developed at the ILL. The project is part of an international collaboration aiming the redefinition of the kilogram on the basis of a natural quantity or of a fundamental constant



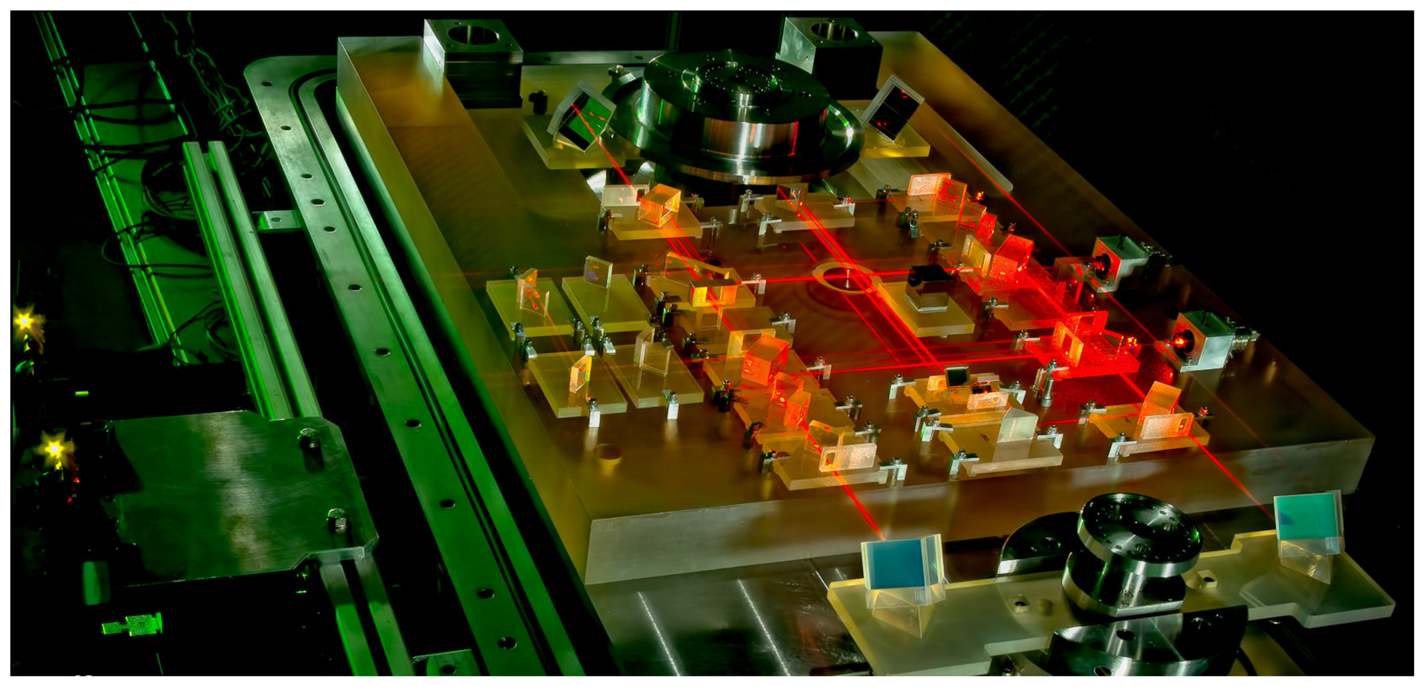
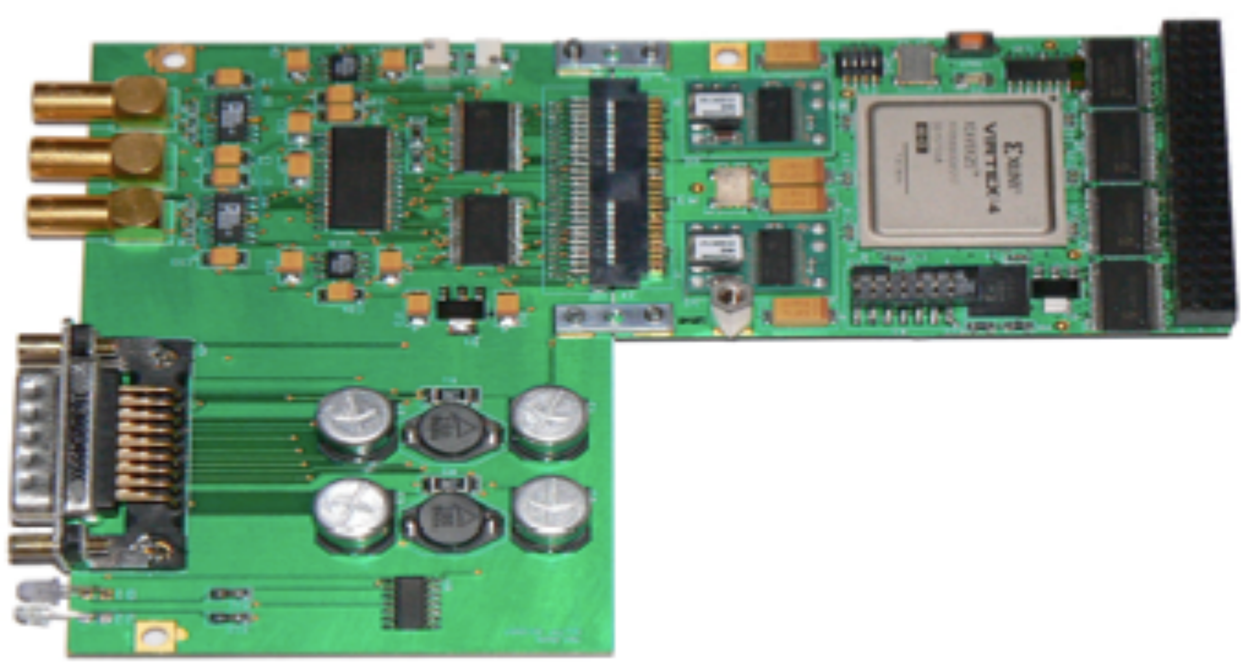


FIG. 1 - The optical interferometer controlling the 2 axis of the ultra high-resolution γ-ray spectrometer GAMS

PHASE READ-OUT AND FINE POSITIONING ELECTRONICS



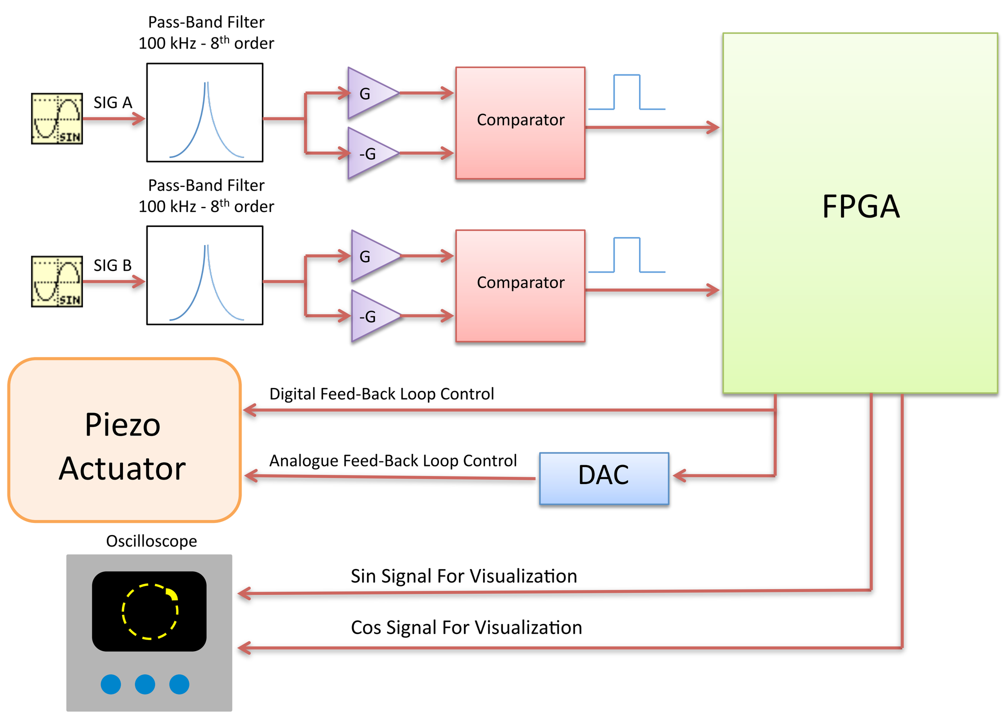


FIG. 2 - Layout of the phase read-out electronics based on a M-Module mezzanine card

The back-end of the mezzanine card contains the FPGA chip and the carrier I/F connector. The front-end implements the analogue circuits necessary to treat all signals from the interferometer as well as all the front-panel connectivity. The module is driven by a master clock running at 100 MHz, which allows the 100 kHz periods to be sampled with an accuracy of ± 10 nsec. This uncertainty is equivalent to 0.0005 interferometer fringes (50 prad). The counting of integer fringes (equivalent to full periods) provides the necessary information for the macroscopic positioning of the spectrometer axes using DC motors coupled to high precision rotation stages. The accuracy of the phase measurement can be pushed up to 0.00005 fringes by means of a sliding average over 100 values, at the price of reducing the sampling frequency down to 1 kHz.

CARD PERFORMANCES

A series of tests have been carried out to evaluate the overall performances of the ILL's phase read-out electronics in comparison with those provided by the commercial dual phase, wide bandwidth, DSP lock-in amplifier SIGNAL RECOVERY model 7280. The lock-in amplifier uses a different approach to derive the phase information. It uses frequency mixing in combination with a low-pass filter to convert the signal's phase and amplitude to a DC voltage signal. Its main advantage is the capability to handle signals with a high signal-to-noise level. All tests were performed using a high precision signal generator feeding both the reference and the interferometer signal therefore, the expected phase difference should be constant.

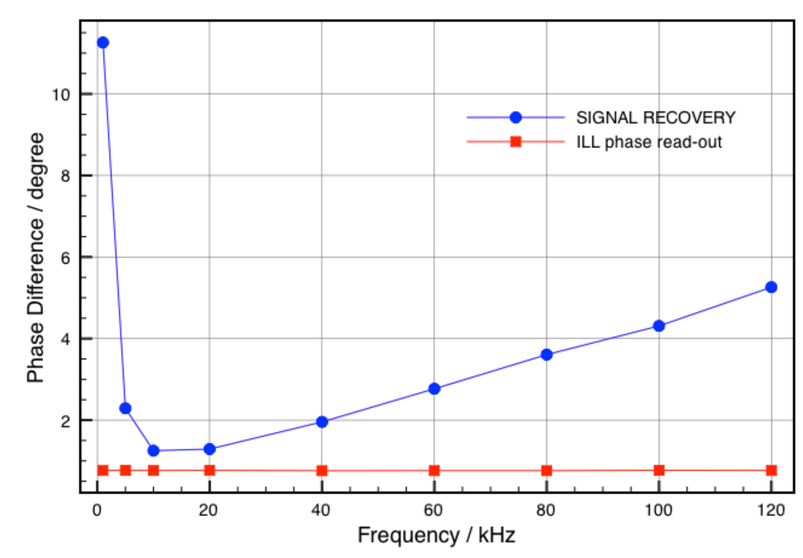


Fig. 3 shows the variation in the measured phase when the beating frequency is increased from 1 kHz up to 120 kHz. The variations observed in the SIGNAL RECOVERY data are probably due to the presence of filters and amplifiers at the input stage.

FIG. 3 - Comparison of the phase offset versus beating frequency

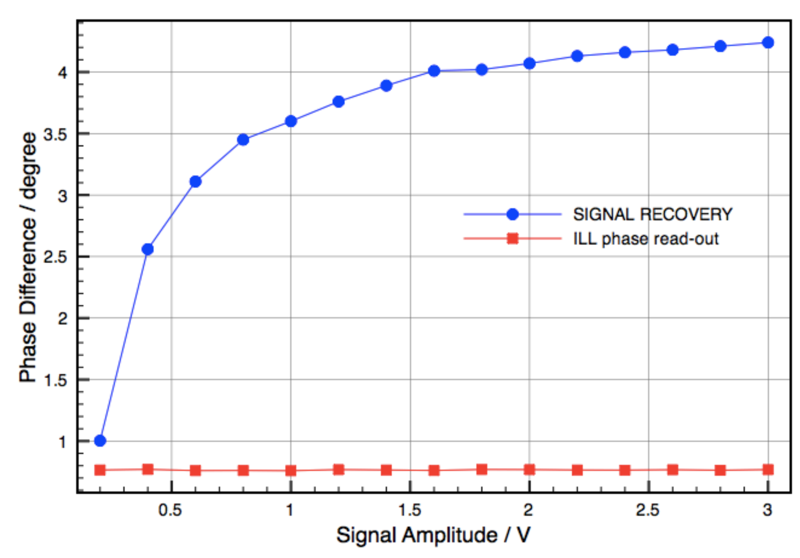
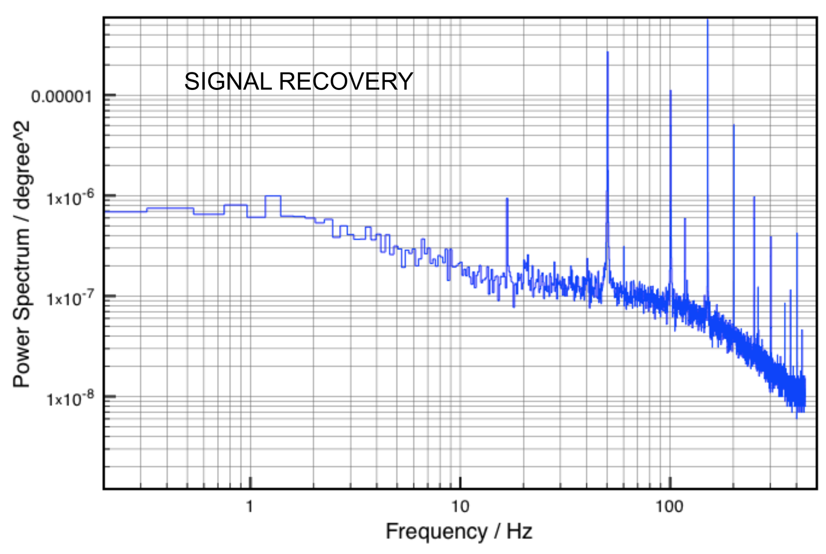


Fig. 4 shows the variation in the measured phase when the input signal amplitude is increased from 100 mV up to 3 V. Our phase read-out electronics does not show any dependency to the signal amplitude.

FIG. 4 - Comparison of the phase offset versus input signal amplitude



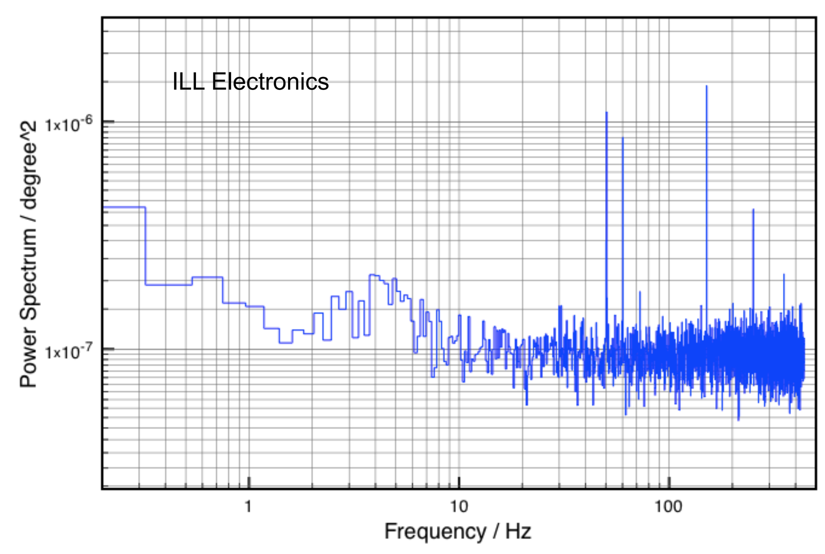


FIG. 5 – Comparison of the power density spectra of the phase difference measured with the SIGNAL RECOVERY lock-in amplifier (left) and with our electronics (right)

The standard deviation of the SIGNAL RECOVERY phase noise (the *rms* value of the signal) - calculated by the square root of the integral spectrum in the 0.1 Hz to 500 Hz frequency interval - is 0.016 degree. The cut-off at about 100 Hz, visible in the left part of Fig. 5, is due to the 1 ms minimum time-constant of the output low-pass filter (6 dB/octave).

The *rms* values are comparable for both the SIGNAL RECOVERY lock-in amplifier and our phase read-out electronics but since for this last one there is no cut-off at 100 Hz, the resulting bandwidth is larger and consequently the total noise lower. At lower frequencies it is evident, especially in the case of the SIGNAL RECOVERY, a slight noise level increase