# Data Acquisition in Laser Spectroscopy for Probing Ultralight Scalar Dark Matter Field Induced Oscillations

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Ultralight scalar dark matter (USDM) couplings to the Standard Model (SM) matter[1] may be addressed in atomic and molecular spectroscopy by recording oscillations of the absorption signal induced at the Compton frequency of the dark matter field. In previous approaches, the absorption signal time series (periodograms) were recorded and Fast Fourier transform of the averaged data[2] was performed with bandwidths up to 250 MHz. The actual needs are for robust, fast, and reliable data acquisition systems with increased acquisition time and more data to reduce noise by averaging, data recording with high duty cycle to enable detection of bursts of the USDM field, high speed in data acquisition and data processing to manage increased Compton frequencies, and, finally, effective timestamping of data to enable correlation of periodograms.

The dark matter direct detection system is a fiber network of laser spectroscopy experiments: a laser, locked to an ultrastable cavity and disseminated remotely by optical fiber links[3], is exploited to probe acetylene reference transitions in the spectral domain at 1.5 μm at different geographical positions. This contribution addresses hardware, timestamping and data flow for a triggerless, continuous and independent, data acquisition system with global time reference provided by the GPS.

Optical detection is performed with a differential photodetector (Thorlabs PDB780CAC) that enables access to low-noise absorption signal with 1 MHz – 2.5 GHz bandwidth. The data acquisition system produced by Renesas provide high-speed serial transmission to a field programmable gate array (Virtex 5, FPGA) using the JESD204B protocol of data acquired with an analog-to-digital conversion card (ISLA214S50, DAQ). The DAQ card ensures 14–bit sampling rates up to 500 MSPS and serial transmission of data with speed up to 3.125 Gbps. Two time-interleaved digital-to-analog conversion channels are available, each with 50% duty cycle and sampling rate up to 250 MSPS. Timing in data acquisition system (sampling clock signal, synchronization signals) is provided using 8V19N850 radio synchronizer and clock jitter attenuator externally referenced to a Symmetricom ExacTime ET6500-OCXO Global Positioning System Time Code and Frequency Generator. The system may be addressed with proprietary software.

For accurate timestamping, a laser driven with an acousto-optic switch time referenced to the GPS is superimposed into the optical spectroscopy detection system. Constant Fraction Discriminator approach is used to enable accurate time referencing in triggerless data acquisition by generating a logical signal from the detected signal that will be used as a timing signal.

[1] D. Antypas *et al*, "New horizons: Scalar and vector ultralight dark matter", arXiv:2203.14915.

[2] O. Tretiak *et al*, "Improved Bounds on Ultralight Scalar Dark Matter in the Radio-Frequency Range", Phys. Rev. Lett., vol. 129, p. 031301, 2022; R. Oswald *et al*, "Search for Dark-Matter-Induced Oscillations of Fundamental Constants Using Molecular Spectroscopy", Phys. Rev. Lett., vol. 129, p. 031302, 2022.

[3] E. Cantin *et al*, "An accurate and robust metrological network for coherent optical frequency dissemination", New J. Phys., vol. 23, p. 053027, 2021.