LASER FREQUENCY COMB BASED WAVELENGTH CALIBRATION TESTED ON THE GIANO-B NEAR-INFRARED SPECTROGRAPH

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INTRODUCTION

High-precision radial velocity measurements require a broadband light source with stable and evenly spaced spectral lines for wavelength calibration. Here, we present an **electro-optic modulation-based laser frequency comb** that is used for calibration and drift measurement of the GIANO-B spectrograph at the Telescopio Nazionale Galileo (TNG) on La Palma, Spain. The most important feature of the EOM-based frequency comb is the line spacing naturally suitable for astronomical spectrographs. The system is all-fibre-based not requiring any alignment or special environment for operation.

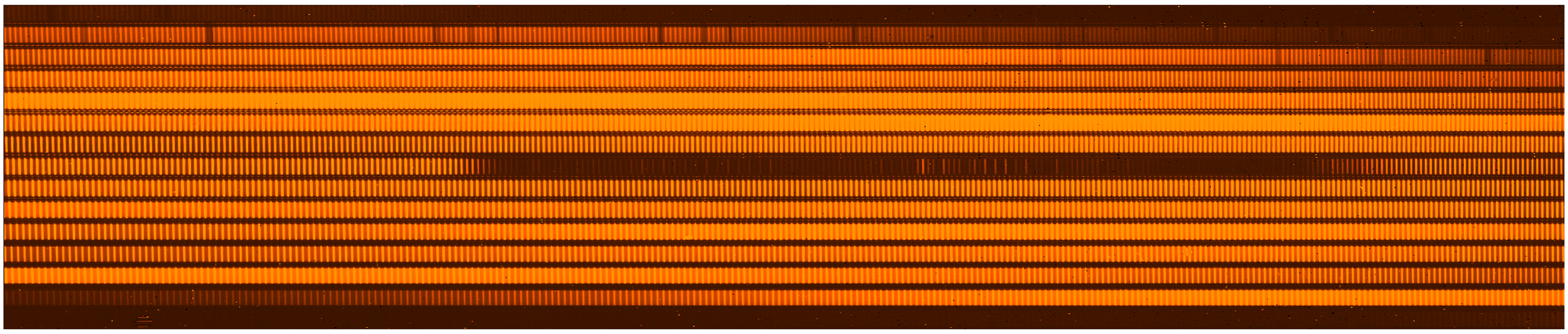

Figure 1: Spectrum of the electro-optic modulation based frequency comb spanning 13 Echelle orders of the GIANO-B spectrograph.

SET-UP

The EOM-based laser frequency comb (LFC) consists of a continuous-wave (CW) light at 1560 nm that is sent through intensity and phase modulators driven by a microwave signal generator at 14.5 GHz which is itself referenced to a 10 MHz signal coming from an atomic clock (Fig.2). The formation of pulses is achieved by cancelling out the chirp via a chirped fibre Bragg grating (CFBG) resulting in a train of pulses with a temporal full width at half-maximum of about 6 ps. The pulses are amplified in an erbium-doped fibre amplifier (EDFA) reaching an average power of 3.5 W. The pulse compression in the carefully chosen optical fibres results in 150-fs duration pulses that are sent through a few meters of a highly-nonlinear fibre for nonlinear spectral broadening. **The resulting spectrum spans nearly 400 nm (from 1400 nm to 1800 nm**) within 20 dB (bottom of the Fig.2). With 1W of output power, the power per mode is roughly 0.1 mW.

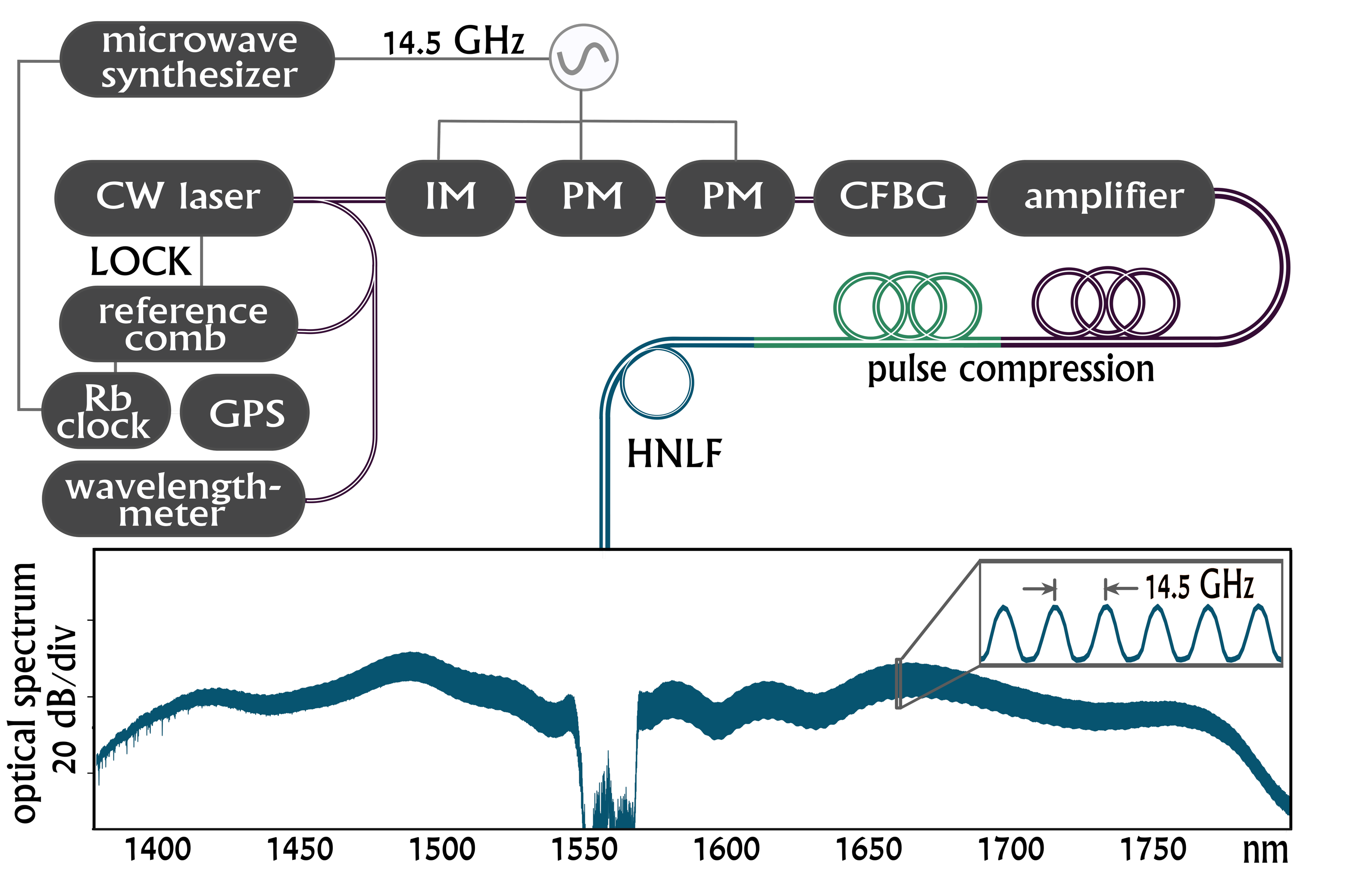

Figure 2: Top: EOM-based LFC set-up. IM - intensity modulator, PM - phase modulator, CFBG - chirped fibre Bragg grating, HNLF - highly nonlinear fibre. Bottom: Spectrum of the EOM-based LFC.

RESULTS

The EOM-based LFC was tested on a GIANO-B spectrograph installed on the Telescopio Nationale Galileo (TNG) in La Palma. GIANO-B operates in the wavelength range from 0.9 μm to 2.4 μm with a resolution of 50'000. A photon-noise limited **wavelength solution with an uncertainty of the order of 10 cm/s** was achieved. Figure 3 shows the spectrograph drift over several hours. Red and blue lines show the radial velocity of the redder and bluer part of the Echelle orders, respectively, indicating a differential drift at both ends of the detector. The LFC agrees well with Un-Ne calibrations that have been performed simultaneously. These results show a great potential of this technology for wavelength calibration of astronomical spectrographs.

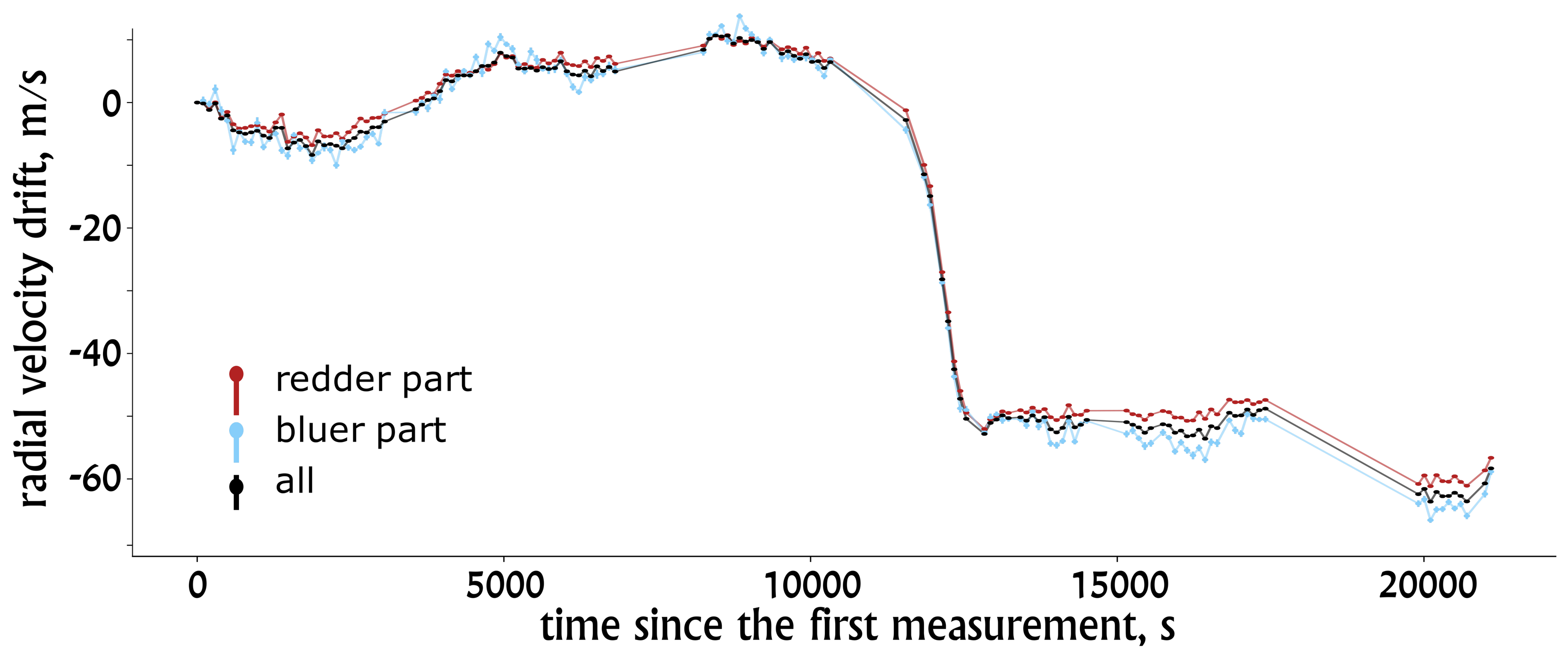

Figure 3: Long term drift of the GIANO-B spectrograph. Black - overall drift, red - drift of the redder part of the spectrograph orders, blue - drift of the bluer part of the spectrograph orders.

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