Low-noise optical frequency divider for precision measurement

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Nowadays, the frequency uncertainties of optical atomic clocks achieve $\sim 1\times10^{-18}$, and the uncertainties induced by optical frequency combs in optical frequency ratio measurement approach to 1.4×10^{-21}[1]. These impressive advances in optical frequency metrology have drawn wide attentions since many precision measurements succeed in gaining higher sensitivity or accuracy by transforming other quantities into a frequency. Among them, search for dark matter, tests of relativity, and detection of gravitational wave anticipate even more precise optical frequency ratio measurement.

Here we report an optical frequency divider (OFD), which can realize optical frequency ratio measurement and optical frequency division to other desired frequencies. The core of the OFD is an optical frequency comb based on a Ti:Sapphire mode-locked laser, which is stabilized to a maser or a rubidium clock for long-term continuous operation. The comb frequency noise in optical frequency division is subtracted via the transfer oscillator scheme [2]. An optically-referenced RF time-base [1], i.e. f_t in Fig. 1(a), is introduced for fine setting of the divisor and low division noise. Moreover, we demonstrate the transportability, long-term operation and multi-channel division of the OFD.

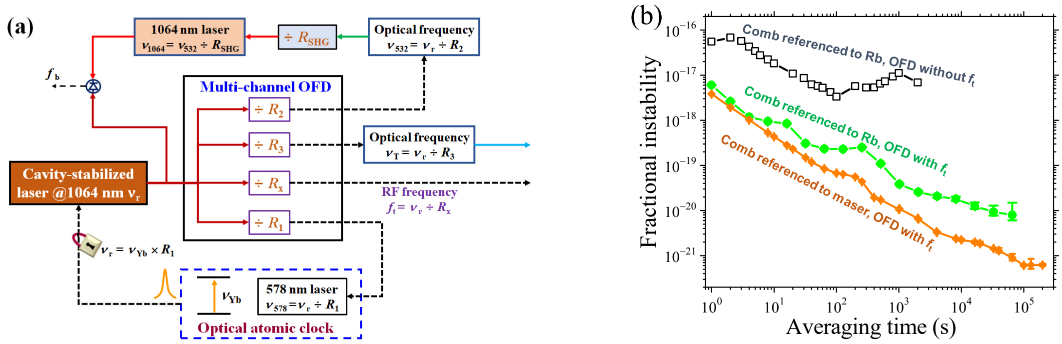

Fig.1. (a) Experimental diagram. We realize a multi-channel OFD, which can be referenced to an ytterbium clock. (b) The division noise induced by the OFD.

Using the OFD when the comb is frequency-stabilized to a maser, we divide the frequency of a cavity-stabilized laser at 1064 nm (ν_r) to 532 nm, $\nu_{532} = \nu_r/R_2$ in Fig. 1(a), while ν_{532} is the second harmonic of an independent 1064 nm laser, $\nu_{1064} = \nu_{532}/R_{SHG}$. By counting the beating frequency between ν_r and ν_{1064}, we measure R_{SHG} to be 2 with a fractional uncertainty of 3×10^{-22}, nearly five times better than previous results [1]. The statistical noise contributed by both the OFD and the second harmonic generation is 4×10^{-18} at 1 s in Fig. 1(b), 10 times smaller than that of the state-of-the-art optical clocks.

To make precision measurement with optical atomic clocks, we also realize an optical frequency synthesizer (OFS) referenced to an ytterbium optical clock [3]. The coherence of a portable cavity-stabilized 1064 nm laser with a frequency instability of 6×10^{-16} at 1 s (as local oscillator) is accurately transferred to a 578 nm laser with the OFD. Despite of megahertz-linewidth comb lines, hertz-level-linewidth ytterbium (Yb) clock transition is resolved, which is then used to faithfully reference the OFS to the ytterbium optical clock by regulating ν_r. Thereby, the output of the OFS is referenced to the Yb optical clock as $\nu_T = \nu_{Yb}\times R_1/R_3$.

References

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