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Microwave Interrogation signal generation system for PTB's caesium fountain clocks

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The PTB employs two caesium fountain clocks CSF1 and CSF2. They are used for the steering of PTB's atomic time scale UTC(PTB) and regularly contribute to the steering of the international atomic time scale TAI. CSF1 and CSF2 have been in operation since 1999 and 2009, respectively. They have been under continuous improvement, reaching systematic uncertainties of 2.8×10^{-16} for CSF1 and 1.7×10^{-16} for CSF2 [1]. Due to their low uncertainty, high uptime and regular operation, the fountains play a valuable role in TAI generation, which is demonstrated by their combined weight of typically 30-50% in TAI calibrations during the last few years.

One key aspect in their improvement has been the revised generation of the 9.19 GHz microwave interrogation signal that is used to probe the atomic resonance. This incorporates the reduction of systematic as well as statistical uncertainties and the assurance of a high uptime, given by high operational reliability and dedicated fallback schemes.

The interrogation signal generation separates into two subtasks. At first a 9.6 GHz microwave signal of high frequency stability is generated and distributed to each fountain. Subsequently, the actual interrogation signal is synthesized and fed to the microwave cavities of the individual fountain clocks.

Formerly a 9.6 GHz DRO was locked via a femtosecond laser frequency comb to an ultrastable CW laser and a hydrogen maser. It has been shown that this approach enabled phase noise levels not exceeding -117 dBc at 10 Hz [2], while causing downtimes due to acoustic sensitivity. More recently the 9.6GHz-signal is more directly generated from a photodiode as the 40th multiple of the repetition rate of a femtosecond laser frequency comb, still locked to an ultrastable CW laser and a hydrogen maser. With this current implementation, a phase noise level of less than -100 dBc at 1 Hz (and – 120 dBc at 10 Hz) has been measured, while due to the reduced acoustic sensitivity uptimes of typically >99% over 30 days are achieved. The microwave signal is routed through a multiplexer unit, which also contains an alternative backup system for the generation of 9.6 GHz. The backup system contains a DRO which is locked to a 5 MHz BVA quartz oscillator steered by a maser by employing a weak lock. In the rare case of a failure of the optically generated microwave signal, this quartz-stabilized 9.6 GHz-signal is fed to the fountains.

Each fountain employs its dedicated synthesizer, used for generation of the 9.19 GHz Ramsey and state selection signals from the 9.6 GHz microwave signal. Both synthesizers feature a frequency detuning scheme to reduce the effect of microwave leakage. Possible phase perturbations in the Ramsey interrogation signal, e.g. caused by the detuning setup, were examined using a home-made sensitive phase transient analyzer [3].

The revised generation of the interrogation signal enables fountain frequency instabilities at the low 10^{-14} level (1s). The systematic uncertainty contribution from the generation of the interrogation signal is 1×10^{-17} [1,3].

References

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