A Compact Optically Pumped Cesium Beam Clock with a Differential Detection Scheme

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Compact cesium beam clocks are one of the most widely used atomic clocks, known for its portability and excellent frequency stability[1]. In recent years, compact optically pumped cesium beam clocks have attracted much attention due to high atomic utilization rate and better frequency stability than the conventional magnetic-state-selected counterparts [2]. However, the actual performance of today's compact optically pumped cesium beam clock is only comparable to that of the magnetic-state-selected one, and fails to reach the expected level. The challenge arises from the increased optical noise when the clock signal is enhanced.

Here we present a differential detection scheme to remove stray light in a compact optically pumped cesium beam clock. The scheme is shown in Figure 1 where an additional fluorescence collector identical to the one in the beam tube is used to collect stray light. The added collector serves as a noise detector since there is no interaction between the laser and the atoms. The structures of the fluorescence collectors are same. The laser is split into two paths. Each path incident into one of the collectors. The laser parameters, including frequency and light power, along with the incident positions of the lasers in the collectors, are identical to ensure same condition during the light collection. At the same time, the angle of the windows in the noise fluorescence collector could fine-tuned to match that of the window in the beam tube. This ensures that the noise characteristics collected by the added fluorescence collector are the same as those in the beam tube. In this way, the pure clock signal is thus derived by differential processing of the clock signal from beam tube with the optical noise collected by the added fluorescence collector.

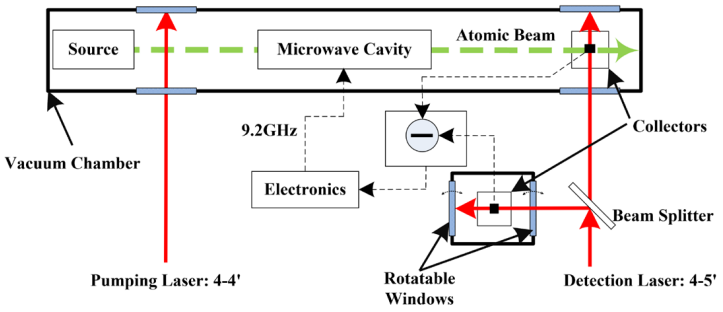

Fig. 1: A schematic diagram of a compact optically pumped cesium beam clock based on differential detection scheme. Both photodiodes in the collectors are the same. The frequencies of the pumping and detection lasers correspond to the 4-4' and 4-5' transition frequencies in cesium, respectively.

In summary, this differential detection scheme enhances the signal-to-noise ratio of the clock signal, improving the short-term frequency stability of compact cesium beam clocks. This optical noise cancellation technique is also applicable to other fluorescence-based atomic beam systems.

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[2] G. Avila, E. De Clercq, M. De Labachellerie, and P. Cerez, "Microwave Ramsey Resonances from a Laser Diode Optically Pumped Cesium Beam Resonator", IEEE Trans. Instrum. Meas., vol. IM-34, pp. 139-143, 1985.