Faraday-rotation Bell–Bloom atomic magnetometer using an alternating pump–probe beam

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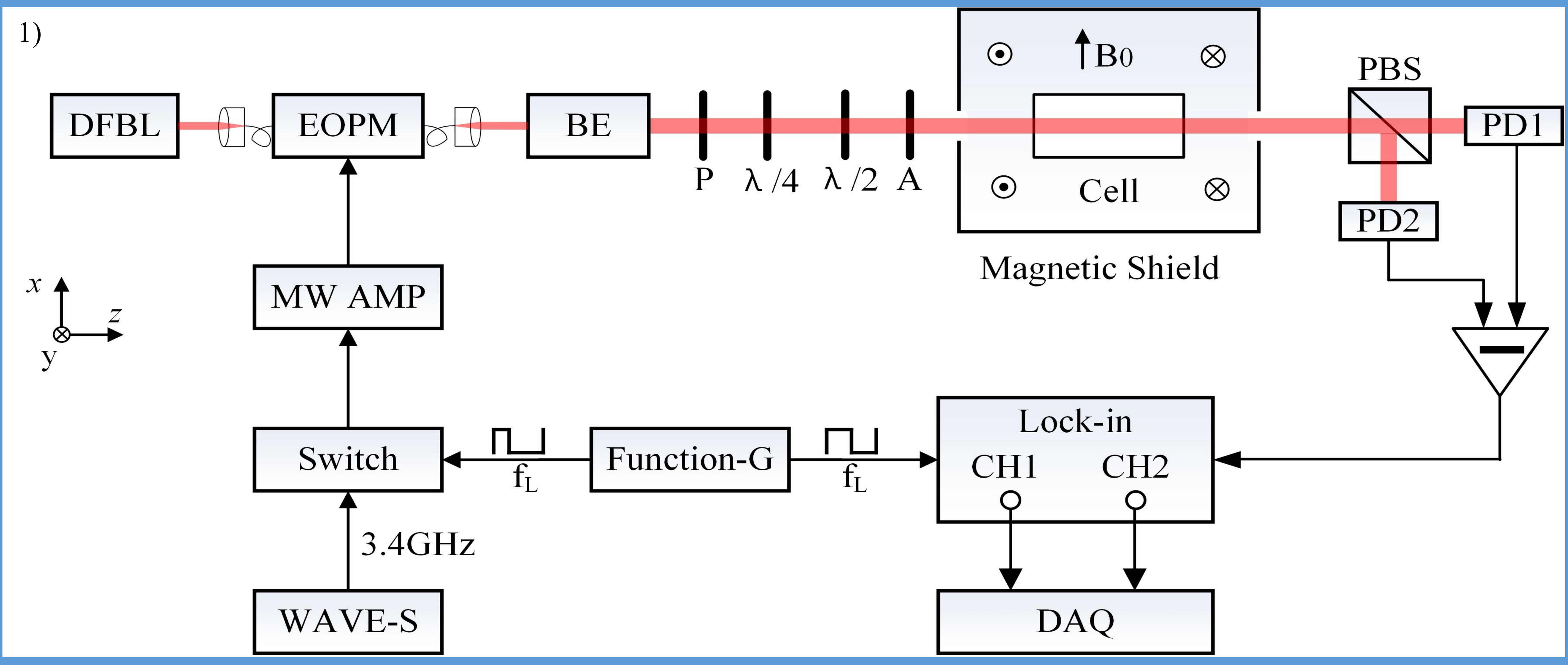
INTRODUCTION

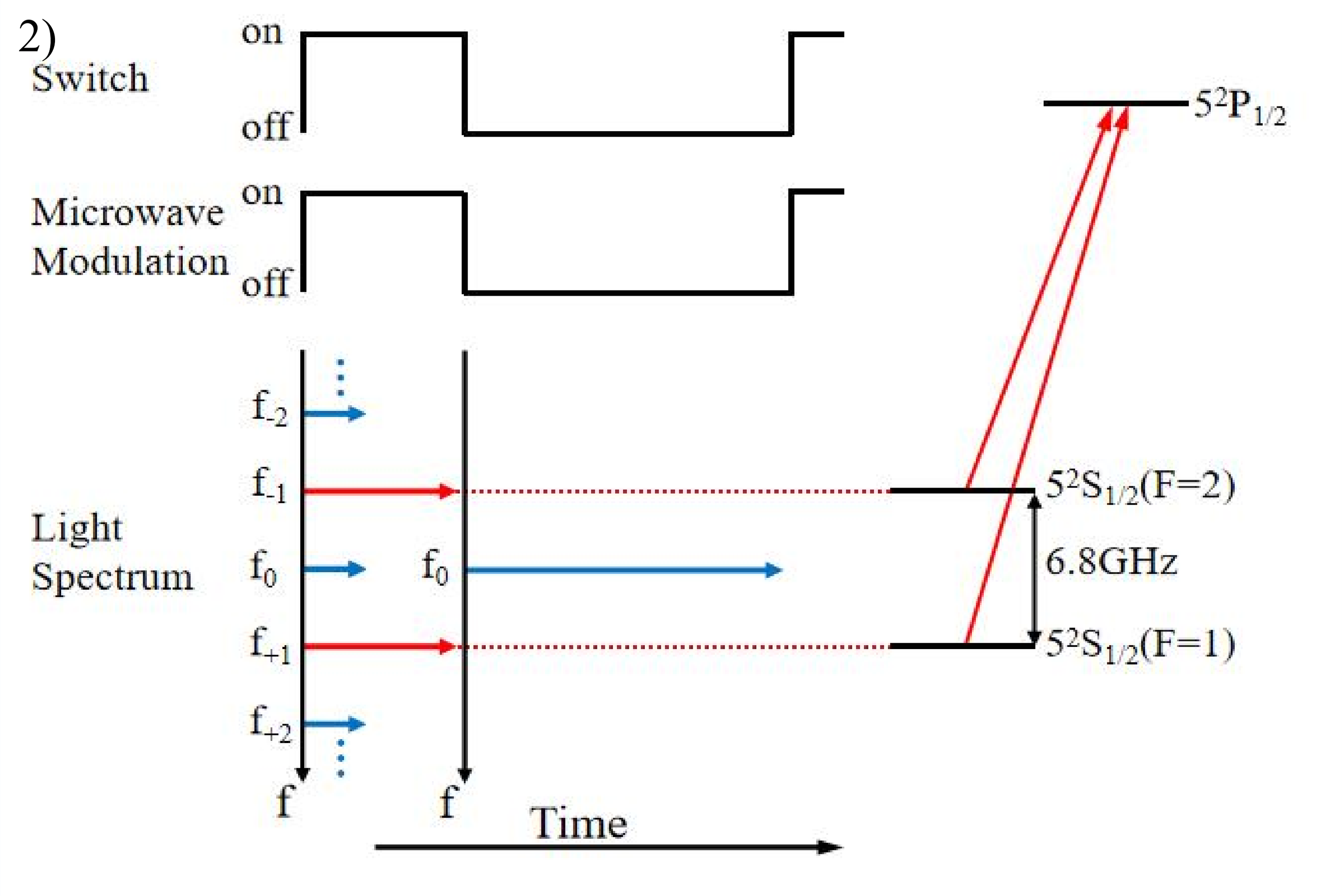
Atomic magnetometers have been widely studied in the past few decades. These devices include nonlinear magneto-optical rotation magnetometers, spin-exchange relaxation-free magnetometers, radio-optical double-resonance magnetometers,and Bell–Bloom magnetometers.Thanks to the all-optical setup, Bell–Bloom magnetometers have the advantage of a simple structure.We propose a scheme for a Bell–Bloom atomic magnetometer based on a single beam.



EXPERIMENTAL SETUP

In our approach, the light is periodically modulated synchronously with Larmor precession. As a result, the light that interacts with atoms is alternately polychromatic and monochromatic.

- When the light is polychromatic, the ±1st sidebands of the light are optically resonant with the atoms, and the atoms are polarized by pumping.
- When the light is monochromatic, a differential detection technique extracts the Faraday-rotation signal of the light, and the polarization of the light is probed.
- The microwave is switched on and off periodically, so the pumping is in the pulse form. When the pulse frequency equals to that of Larmor precession, coherent pumping and magnetic resonance are achieved.

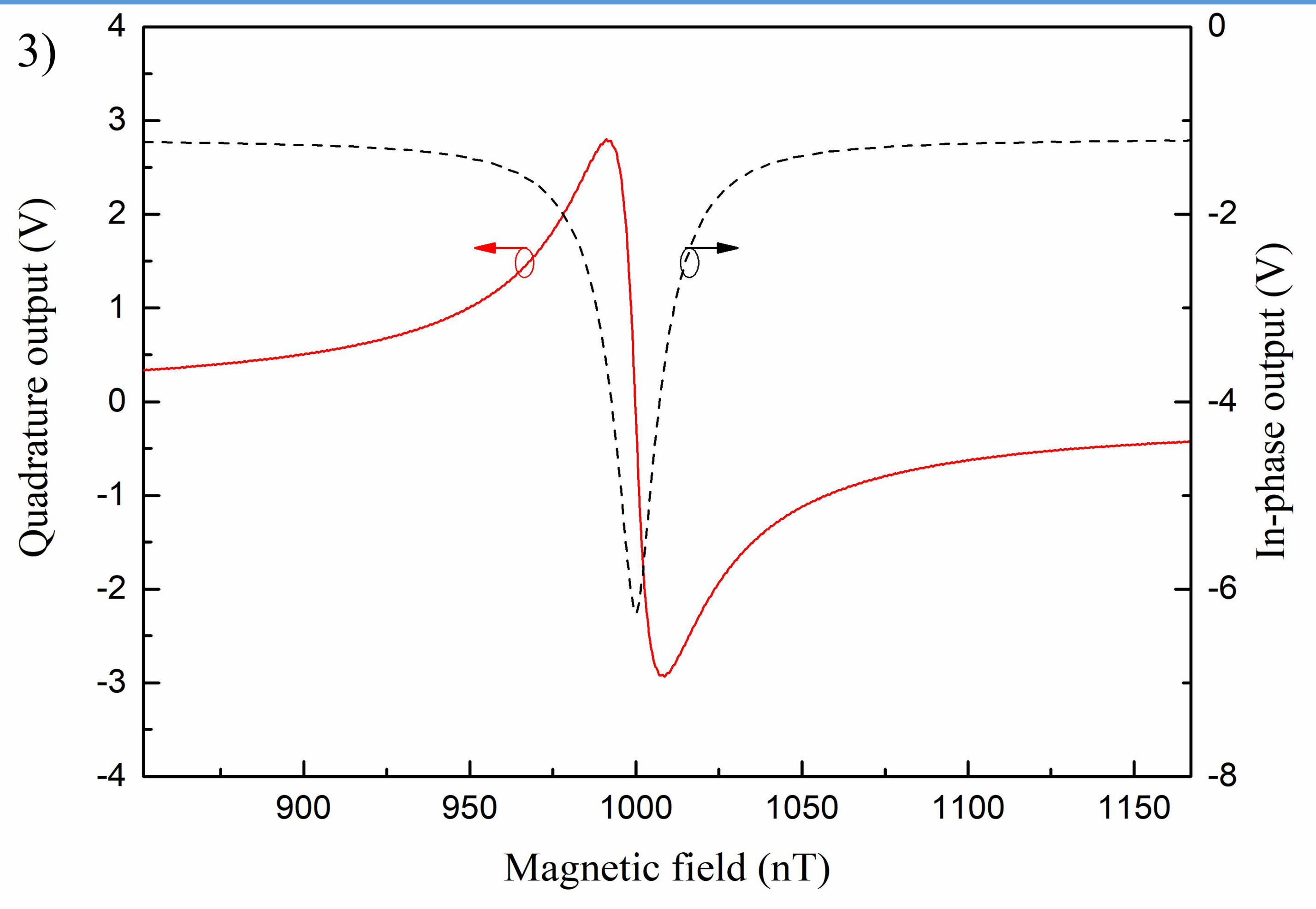


MAGNETIC-RESONANCE SIGNAL

The measured magnetic field B_0: 1 μT, corresponding to a Larmor frequency of 7 kHz.

Magnetic resonance is achieved by slowly ramping B_0 around 1 μT by changing the injection current of the Helmholtz coil. Magnetic-resonance signal is shown in Fig.3:

- The black dashed curve is the absorptive in-phase signal
- The red solid curve is the dispersive quadrature signal for magnetic-field discrimination.

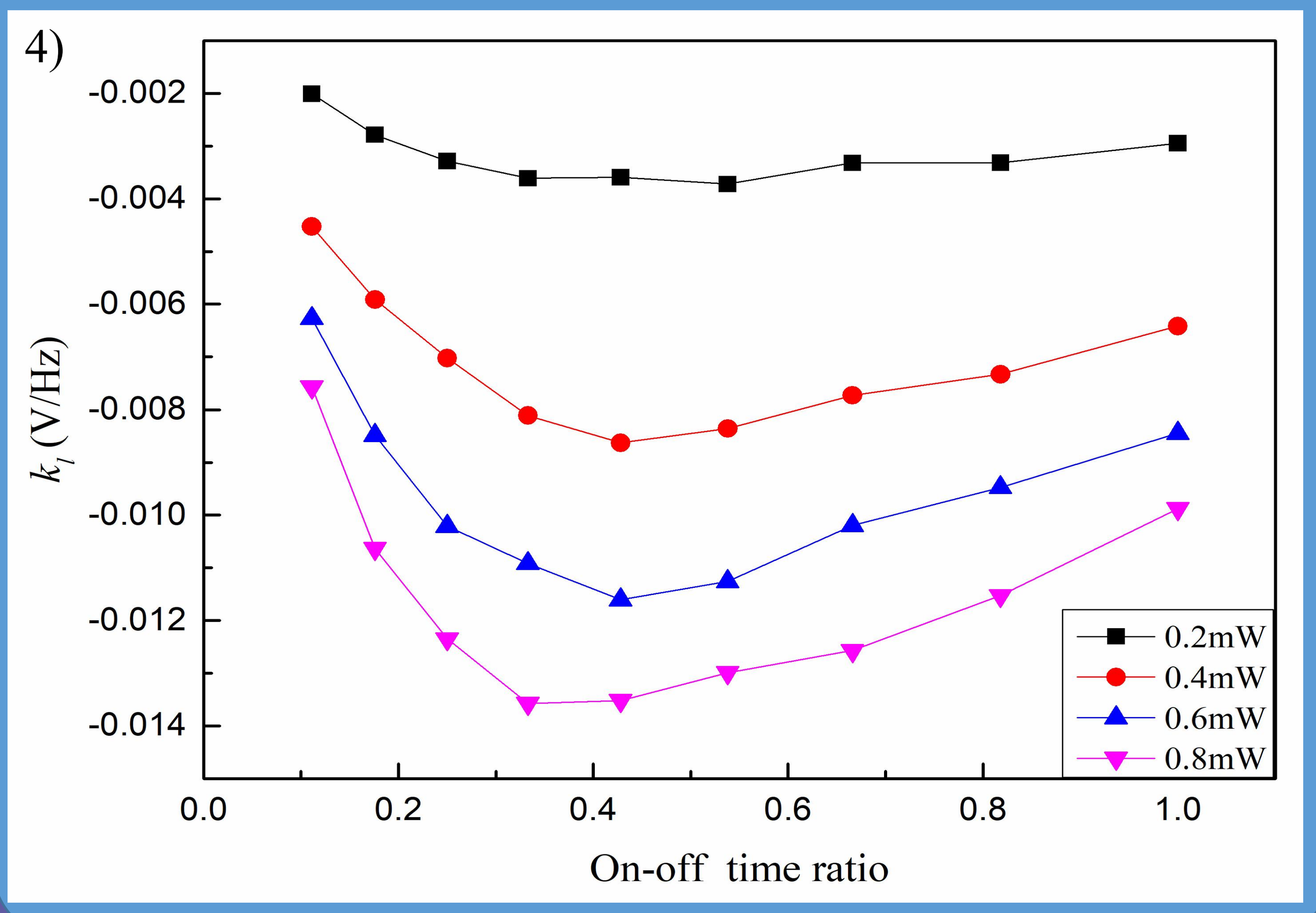


PARAMETER OPTIMIZATION

The on–off time ratio for the switch, i.e., pumping time/probing time, influences the pumping and probing effects in the presented scheme:

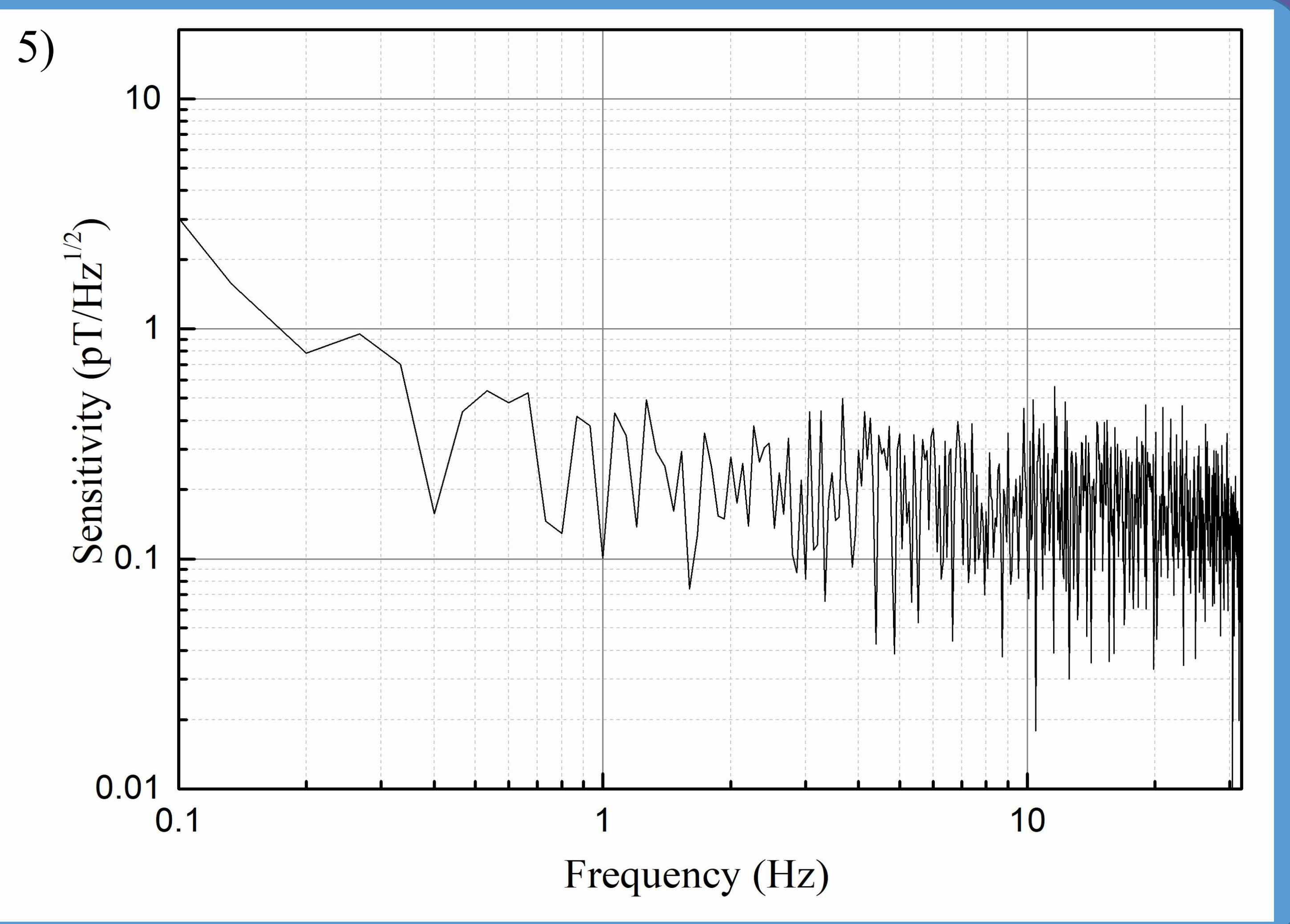
- The shorter the pumping time is, the more coin cident the phase of the atoms is and the stronger the effect of coherent pumping is.
- The polarization of the atoms depends on the pumping time.

The optimum on–off time ratio is between 0.3 and 0.6 (Fig.4).



CONCLUSION

- The technology for probing Faradayrotation is suitable for highly sensitive atomic magnetometers.
  Sensitivity : 0.25pT/Hz$^{1/2}$ at 1 Hz, 0.2 pT/Hz$^{1/2}$ at 10–30Hz (Fig.5).
- The sensor head of the atomic magnetometer has a relatively simple structure apart from the optics for polychromatic-beam generation.
- Structure of a single beam is suitable for developingcompact, miniaturized magnetometers.
- The all-optical structure is conducive to the realization of magnetic field gradiometers and magnetic measurement arrays.



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