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OPTICALLY DRIVEN ATOMIC RESONATOR SYSTEMS EMPLOYING MEANS FOR MODULATING THE SENSE OF ROTATIONAL POLARIZATION OF THE PUMPING LIGHT

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ABSTRACT OF THE DISCLOSURE

The present invention relates in general to optically driven spin precession of atomic resonator systems, such as employed in atomic frequency standards and atomic vapor magnetometers and, more particularly, to improved systems of this type employing means such as a Pockels cell for modulating the polarization of the driving light of a beam of light between left and right hand rotational polarization at a certain frequency to produce precession of the atomic resonators. In the case of a vapor magnetometer, the alternating left and right hand polarization produces precession of the atomic resonators without intensity modulation of the applied radiation. In the case of the atomic frequency standard, the alternating left and right hand polarized light is passed through a left hand or right hand circular polarizer before application to the atomic resonators for producing either a right hand or left hand circularly polarized wave which is intensity modulated at the certain frequency for driving spin precession of the atoms.

DESCRIPTION OF THE PRIOR ART

Heretofore, spin precession of a system of atomic resonators such as Rb, Cs, He, Hg, K or Na vapor has been produced by driving the system of atomic resonators with optical radiation modulated at a certain frequency, typically the atomic resonant (spin precession) frequency. Such an arrangement is described and claimed in U.S. Patent 3,173,082 issued Mar. 9, 1965, and assigned to the same assignee as that of the present invention.

In the prior atomic vapor magnetometer, the applied optical radiation was modulated in intensity at the precession frequency to produce spin precession (resonance) of the atomic resonators. The resonance of the atomic resonators was detected by a photocell monitoring the absorption of the applied radiation by the precessing atomic resonators. The absorption was detected by monitoring the intensity of a beam of light passing through the atomic vapor to the photocell. The precessing atoms modulate the intensity of the light, as monitored by the photocell, at the precession frequency and at harmonics thereof. However, detection of the precession absorption component in the detected light signal is very difficult because this signal is masked by the applied intensity modulation of the light at this frequency, which applied modulation was necessary to produce precession of the atoms. Therefore, it was proposed to employ the second harmonic of the detected precession signal and to divide this signal by two and feed it back to the light intensity modulator to provide sustained precession of the atoms. This scheme has its difficulties as well.

In the case of the atomic frequency standard, the intensity modulation of the driving optical radiation is typically at a much higher frequency corresponding to a field independent hyperfine resonance transition. It was proposed to modulate the intensity of the driving light by means of a Kerr cell or by modulating the intensity of the R.F. excited lamp, which lamp served as the source

of optical radiation. However, it is difficult to use these means for continuously modulating the intensity of the optical radiation at frequencies high enough to reach many of the hyperfine frequencies which can range between 252 mHz. for potassium 41 and 9193 mHz. for cesium.

SUMMARY OF THE INVENTION

In the present invention, means such as a Pockels cell is provided for moduating the sense of the circular polarization of a beam of optical pumping radiation at a frequency to produce spin precession of an atomic resonator system. Such a modulator is capable of operating up to frequencies including the hyperfine resonance frequencies.

In the case of an atomic vapor magnetometer, the circular polarization modulator modulates the sense of the circular polarization of the optical radiation applied to the atomic vapor. The modulation frequency is chosen at a frequency to produce spin precession of the atomic resonators at a frequency dependent upon the magnitude of the magnetic field in the atomic vapor. The spin precession of the atomic resonators is detected by monitoring spin precession amplitude modulation of the optical radiation passing through the vapor. The spin precession frequency is detected and serves as a measure of the magnetic field intensity. A major advantage of a Pockels cell modulator is that the intensity of the applied optical radiation need not be modulated to produce spin precession, thereby facilitating detection of the intensity modulation of the transmitted portion of the applied radiation due to spin precession of the atomic resonators. In other words, the spin precession modulation of the monitored light is not masked by pre-modulating the intensity of the applied optical radiation to produce the spin precession.

In a preferred embodiment of the magnetometer of the present invention, a detected spin precession signal component of the monitored light is fed back to the rotational polarization modulator (Pockels cell) for modulating the polarization of the applied optical radiation at a frequency to produce self-sustaining spin precession of the atomic resonators. The spin precessions are, thus, self-sustaining at a frequency dependent upon the intensity of the magnetic field. A measure of this frequency is a measure of the magnetic field.

In an atomic frequency standard embodiment of the present invention, the applied optical radiation is intensity modulated at the hyperfine resonance frequency, because the atomic resonators do not possess a magnetic polarization that can be coupled to merely by modulating the sense of the polarization of the applied radiation. However, the circular polarization modulator, such as the Pockels cell, is converted into an intensity modulator by passing its output through either a left hand or right hand circular polarizer, thereby chopping the light into pulses of constant intensity of only one sense of polarization, such pulses occurring at the modulation frequency. Hyperfine resonance of the atomic vapor is detected and used to control the output frequency of the standard.

The advantage of the intensity modulator employing the Pockels cell as a component is that it readily permits continuous intensity modulation of the applied optical radiation at the relatively high frequencies of the hyperfine resonance transitions. Prior Kerr cells tend to overheat during prolonged continuous operation at microwave frequencies.

The principal object of the present invention is the provision of improved optically driven atomic resonator systems.

One feature of the present invention is the provision of a modulator for modulating the optical radiation ap-