Applications

Electronics Development

Hypothesis

By increasing cell temperature, the sensitivity improves due to the greater number of Cs atoms, and the bandwidth goes up due to the increased rate of collisions. We win on both avenues...

Optical pumping is used to produce a net magnetic moment in the Cs cell. Light of the correct wavelength and polarization will de-populate some states thereby creating an net magnetic moment.

The precessing magnetic moments may be interrogated optically as well. At the atom traps, they modulate the intensity of the light beam passing through the cell. The frequency of the modulation will be proportional to the magnetic field being measured.

Initial Results

In laboratory experiments with 1 mm cells, we found that at the required temperature, the cells become nearly opaque to the laser beams. The loss of signal lowers the performance of the devices.

Later Results

By using an off-resonance polarization rotation scheme, we have achieved the project goals of 10 pT sensitivity and 10 kHz bandwidth.

Wide Band Sensors

Miniaturizing the total-field sensor consists of the following tasks:

• Develop efficient method of fabricating and filling a MEMs cell with the correct mixture of gases. Determine stability of the mixture.

• Develop methodology for coating cell walls to reduce signal losses due to wall diffusion through buffer gas and wall.

• Bond top and bottom of the cell to Pyrex to Si.

• Design a mechanical structure with the required elements for the sensor head ("physics package")

• Implement the electronics design for low power and small size

We have just finished building a test platform to allow us to take measurements in the field, ensuring the system is tolerant of spatial and temporal gradients. Data taken while waving an object in the vicinity of the sensor is shown below.

To do this, the bandwidth of the sensor needs to be increased to 10 kHz or so.

By reducing cell temperature, the sensitivity improves due to the greater number of Cs atoms, and the bandwidth goes up due to the increased rate of collisions. We win on both avenues.

1. Optical pumping is used to produce a net magnetic moment in the Cs cell. Light of the correct wavelength and polarization will de-populate some states thereby creating a net magnetic moment.

2. The precessing magnetic moments may be interrogated optically as well. At the atom traps, they modulate the intensity of the light beam passing through the cell. The frequency of the modulation will be proportional to the magnetic field being measured.

3. This process must be done minimizing any cross talk or coupling from interfering with the signal of interest. The laser must be brought to the correct wavelength. The correct modulation signals must be applied to the laser or H1 coil. The photodiode signal must be amplified and processed.

We have just finished building a test platform to allow us to take measurements in the field, ensuring the system is tolerant of spatial and temporal gradients. Data taken while waving an object in the vicinity of the sensor is shown below.

The device at the left is 1 cm across. This is an actual atomic clock developed by Symmetron with DARPA funding. Ultimately, this can be the size of our magnetometer sensor.

These photos show the difficulties in building existing total field magnetometers. In order to best identify the object underground, a high density of readings is desirable. This requires several sensors, which create large, bulky platforms.

Miniaturizing the total-field sensor consists of the following tasks:

• Replace the high power Cs-discharge lamp with a laser diode light source.

• Miniaturize the head-box Cs cell to reduce the power required to heat the cell.

• Apply recent advances in signal interrogation techniques to recover the sensitivities lost in reducing the size of the cell.

• Design a mechanical structure with the required elements for the sensor head ("physics package")

• Implement the electronics design for low power and small size

We have built a test structure to measure the performance of the various components of the sensor. This device is much larger than the final sensor package we will need to be. The interior components themselves are only a few mm across, while the entire structure is 1 inch across.

Objective

Current generation total field magnetometers are extremely large, bulky, and they consume a lot of power. The future requires large, heavy batteries. Funded by DARPA, recent technologies have been developed towards miniaturizing atomic clocks. Since atomic clock technology is closely related to total-field magnetometer technology, we are applying these techniques towards total-field magnetometers.

Background

Atomic magnetometers operate by measuring the precession frequency of a magnetic moment around the magnetic field of interest. The precession frequency is proportional to the magnetic field.