NUCLEAR MAGNETIC RESONANCE GYROSCOPE

TECHNICAL FIELD

The invention relates generally to nuclear magnetic resonance and more particularly to nuclear magnetic resonance gyroscopes.

BACKGROUND

A nuclear magnetic resonance (hereinafter referred to as NMR) angular rate sensor or gyroscope is described in U.S. Pat. No. 4,157,495, the disclosure of which is hereby incorporated by reference into this document. A NMR gyroscope operates on the principle of sensing inertial angular rotation rate or angular displacement about a sensitive axis of the device as a shift in the Larmor precession frequency or phase, respectively, of one or more isotopes that possess nuclear magnetic moments.

The gyroscope is composed of an angular rotation sensor and associated electronics. The principal elements of the sensor are a light source, an NMR cell, a photodetector, a set of magnetic shields and a set of magnetic field coils. The principal elements of the electronics are signal processing circuits for extracting the Larmor precession frequency and phase information as well as circuits for generating and controlling various magnetic fields, both steady and varying sinusoidally with time, that are necessary for the proper operation of the device.

The NMR cell is mounted within a set of magnetic shields in order to attenuate external magnetic fields to acceptable low levels. Magnetic field coils are used to apply very uniform magnetic fields to the NMR cell. Both a steady field and an ac carrier field are applied along the sensitive axis of the device and AC feedback fields are applied along one of the transverse axes. The DC magnetic fields along both transverse axes are controlled to be substantially zero. The NMR cell contains one or more alkali metal vapors, such as rubidium, together with two isotopes of one or more noble gases, such as krypton-83, and xenon-129, or xenon-131. One or more buffer gases such as helium and nitrogen may also be contained in the cell. The NMR cell is illuminated by a beam of circularly polarized light that originates from a source such as a rubidium lamp and which passes through the cell at an angle with respect to the steady magnetic field. Absorption of some of this light causes the atomic magnetic moments of the rubidium atoms to be partly aligned in the direction of the steady magnetic field. This alignment is partly transferred to the nuclear magnetic moments of the noble gases, and these moments are caused to precess about the direction of the steady magnetic field, which in turn creates magnetic fields that rotate at the respective Larmor precession frequencies of the two noble gases. These rotating fields modulate the precessional motions of the rubidium magnetic moments, which in turn produce corresponding modulations of the transmitted light, thereby making it possible to optically detect the Larmor precession frequencies of the two noble gases.

The modulations of the light intensity are converted into electrical signals by a photodetector, and these signals are then electronically demodulated and filtered to provide signals at the Larmor precession frequencies of the two noble gases. The difference between the two precession frequencies is used to accurately control the steady magnetic field so that it is constant. One of the noble gas precession frequencies is subtracted from a precision reference frequency. The resulting difference frequency is a measure of the angular rotation rate of the gyroscope. The magnitude of an individual nuclear magnetic moment is extremely small and the natural equilibrium condition is one in which a nearly random orientation of moments exists in an ensemble of atoms. Techniques must be used to orient a significant fraction of these magnetic moments in a single direction so that a macroscopic magnetic moment, and consequently a measurable signal, will be produced.

SUMMARY

The invention in one implementation encompasses a method. A nuclear magnetic resonance cell with first, second, and third nuclear moment gases and at least one optically pumpable substance is provided. First, second, and third measured precession frequencies that correspond to the first, second, and third nuclear moment gases are obtained. The first, second, and third measured precession frequencies are altered from corresponding first, second, and third Larmor precession frequencies by a rotational rate and corresponding first, second, and third local magnetic fields. The rotational rate is determined with compensation for the first, second, and third local magnetic fields through employment of the first, second, and third measured precession frequencies.

Another implementation of the invention encompasses an apparatus. The apparatus comprises a nuclear magnetic resonance cell and a photodetector. The nuclear magnetic resonance cell comprises first, second, and third nuclear moment gases and at least one optically pumpable substance. The nuclear magnetic resonance cell receives detection light that passes through the nuclear magnetic resonance cell. The first, second, and third nuclear moment gases and the at least one optically pumpable substance cooperate to modulate the detection light based on local magnetic fields and pass transmitted light to the photodetector. The photodetector receives the transmitted light through the nuclear magnetic cell and determines a rotational rate with compensation for the first, second, and third local magnetic fields.

DESCRIPTION OF THE DRAWINGS

Features of various implementations of the invention will become apparent from the description, the claims, and the accompanying drawings in which:

The FIGURE is a representation of one implementation of an apparatus that comprises a nuclear magnetic resonance cell and a photodetector.

DETAILED DESCRIPTION

The nuclear magnetic resonance ("NMR") gyro disclosed in U.S. Pat. No. 4,157,495 employs two noble gas species as rotation detectors based on the following equations of precession:

$$\omega_1=\gamma_1 H-\Omega \quad (1)$$

$$\omega_2=\gamma_2 H-\Omega \quad (2)$$

where the subscripts refer to one or the other of the noble gas species, and where H is the applied magnetic field, γ is the gyromagnetic ratio for the noble gas nuclear spin, Ω is the vehicle rotation rate and ω is the measured precession frequency.

Since equations (1) and (2) are a system of linear equations with two unknowns, H and Ω, unique solutions,