

## Implementation of control algorithm for Ring Laser Gyroscope

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### ABSTRACT

Ring Laser Gyro(RLG) is used to sense angular information accurately and precisely. RLG mainly depends on the pathlength, intensity and dithering. If path length changes there will be change in the intensity. By using RLG model equations, the path length, intensity and dithering can be controlled. By digitalising the output signals and developing a suitable algorithm and implemented in FPGA. This system is used in robotics and space vehicles for tracking, balancing and controlling the motion.

*Keywords* - Dithering, FPGA, Intensity, Pathlength, RLG.

### I. INTRODUCTION

Guidance, navigation and control systems both in aircrafts and spacecrafts require gyroscopes to maintain orientation in flight. In particular, the measurement of the angular motion of a satellite in the space is essential for the control and stabilization of its attitude. Systems employing a gyroscope include the control and processing electronics to provide the most direct method for sensing inertial angular velocity. In inertial navigation systems, which uses gyroscopes to measure rate of rotation and acceleration, measurements are integrated once or twice to yield position. Inertial navigation systems also have the advantage that they are self-contained. On the downside, inertial sensor data drifts with time because of the need to integrate rate data to yield position; any small constant error increases without bound after integration. Another problem with inertial navigation is the high equipment cost. For example, highly accurate gyros, used in airplanes, are prohibitively expensive. Very recently, laser gyros, which are very accurate, have become more attractive as alternative solutions because of their lower cost.

### II. NAVIGATIONAL GYROSCOPE

A gyroscope is a device for measuring or maintaining orientation. A mechanical gyroscope is

based on the principles of conservation of angular momentum. It is a spinning wheel or disk whose axle is free to take any orientation. This orientation changes much less in response to a given external torque than it would without the large angular momentum associated with the gyroscope's high rate of spin. Since external torque is minimized by mounting the device in gimbals, its orientation remains nearly fixed, regardless of any motion of the platform on which it is mounted.

Gyroscopes based on other operating principles also exist, such as the electronic, microchip-packaged MEMS gyroscope devices found in consumer electronic devices, fibre optic gyroscopes, and the extremely sensitive ring laser gyroscope.

Applications of gyroscopes include navigation when magnetic compasses do not work or are not precise enough. It is also used for the stabilization of flying vehicles like radio-controlled helicopters. Due to higher precision, gyroscopes are also used to maintain direction in tunnel mining.

### III. RING LASER GYROSCOPE

Lasers with ring cavity can be used to measure angular rotation with great accuracy and precision. These active sensors show a wide dynamic range and a fast update rate. They are vibration insensitive and have a long and reliable lifetime, about > 30,000 hours. Disadvantages are mainly some performance limitations as null shift and lock-in effect. The key properties of the laser that make the laser based rotation sensor possible are the laser's coherent, highly directional, monochromatic light beam. RLG works on the principle of the Sagnac effect. The RLG consists of two laser beams travelling in opposite direction over a closed path created by mirrors.

The first experimental ring laser gyroscope was demonstrated in the US by Macek and Davis in 1963. The technology has since been developed by a number of companies and establishments worldwide. Many tens of thousands of RLGs are operating in inertial navigation systems and have established high accuracy.

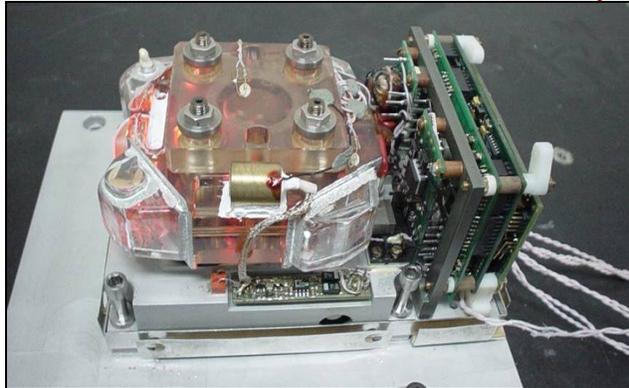


Figure 1: Ring laser gyroscope

Ring laser gyroscopes can be used as the stable elements in an inertial reference system. The advantage of using an RLG is that there are no moving parts. Compared to the conventional spinning gyroscope, this means there is no friction. This in turn means there will be no inherent drift terms. Additionally, the entire unit is compact, lightweight and virtually indestructible. Thus it can be conveniently used in aircraft.

Primary applications of the laser gyro include navigation systems on commercial airliners, ships and spacecraft. RLGs are often part of Air Data Inertial Reference Units. In these applications, it has replaced its mechanical counterpart, the Inertial guidance system. RLG based inertial systems are beginning to find promise for applications such as advanced military interceptor technology and commercial space satellite navigation, guidance and control systems.

#### IV. PATH LENGTH CONTROL

It relates to means for controlling the path length of a ring laser gyro, and has particular relation to such means which are as completely digital as possible.

In a ring laser gyro (RLG), an optical ring is formed, and two laser beams are directed around the ring in opposite directions. When the beams are combined, rotation of the ring appears as an interference shift in the combined beams.

It is apparent that precise control must be maintained over the optical length of the path which the beams take around the ring. The conventional method is analog dithering. At point 10, the path length is too short for the laser to produce its maximum output: at point 12 it is too long; and at point 14 it is just right.

The path length of an RLG can easily be controlled, by controlling the position of one (or more) of the mirrors which bounce the laser beams around the ring.

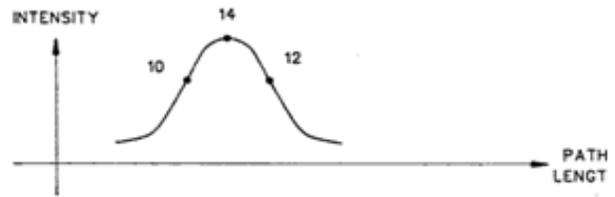


Figure 2: Intensity of light vs Path length

This may most conveniently be accomplished by placing a piezoelectric transducer (PZT) on the back of the mirror, and controlling the thickness of the PZT by controlling the voltage which is fed to the PZT. If the RLG is operating at point 10, then the voltage to the PZT is increased: if the RLG is operating at point 12, the voltage is decreased; and if the RLG is operating at point 14, the voltage is kept constant. The PZT is constructed such that increasing the voltage makes the PZT thinner, which (since the PZT is on the back of the mirror) increases the path length. Decreasing the voltage decreases the path length. Voltage polarity, PZT position, and PZT operation (increased voltage makes it thicker) may be reversed in pairs if convenient.

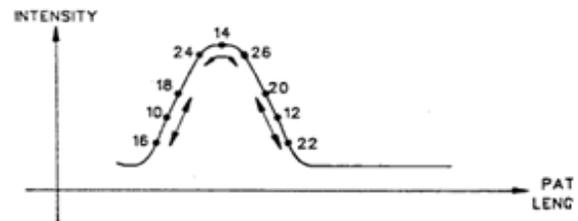


Figure 3: Intensity vs path length for dithering operation

Dithering is used to determine the point at which the RLG is operating. Dithering is the application of a small AC sinusoidal voltage signal to the PZT, causing the path length of the RLG to likewise vary sinusoidally. If the RLG was operating at point 10 without dithering, then it will operate at point 16 and 18, and at every point in between, with dithering. If the RLG was operating at point 12 without dithering, it will instead operate between points 20 and 22; and, if previously operating at point 14, it will now operate between points 24 and 26.

#### V. BLOCK DIAGRAM

The variation in path length will lead to a change in scale factor and hence a path length control loop is required. For that one needs to know whether the path is stable or changing. By monitoring intensity variation

alone will not be sufficient to do that. Therefore the path length is modulated by some means and the resulting intensity modulation is extracted. This demodulated beam is compared with the reference signal to generate an error signal which in turn will be fed to the means of the path control to take the necessary adjustments. RLG model having the standard equations for the beam1 and

spring driven at its resonance frequency. This ensures that the angular velocity of the system is usually far from the lock-in threshold. Typical rates are 400 Hz, with a peak dither velocity of 1 arc-second per second. Dither does not fix the lock-in problem completely, as each time the direction of rotation is reversed, a short time interval exists in which the rotation rate is near zero and lock-in can briefly occur.

The sin/cos signals from the photo detectors are frequency modulated by the dither. Thus the signals contain the rotation due to the dither as well as the actual rotation. In order to obtain the count due to the actual rotation the effect of dither has to be removed from the signals.

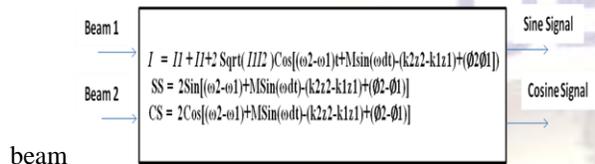


Figure 4: RLG Model

The two 90° out of phase signals from the photo detectors in the RLG are referred to as the sin/cos signals. The photo detectors produce a signal of 30µA. A transimpedance amplifier amplifies the photo detector signals to 1V signals which are further amplified by an amplifier card in the RLG to a 5V p-p signal. The sin/cos signals have a frequency range spanning from 10Hz to 1MHz.

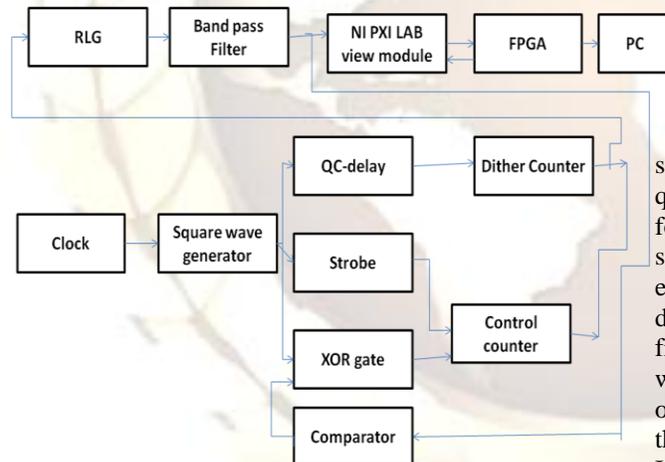


Figure 5: Block diagram

RLG suffers from an effect known as lock-in at very slow rotation rates. When the ring laser is hardly rotating, the frequencies of the counter-propagating laser modes become almost identical. In this case coupling in between the counter-propagating beams can allow for static locking so that the standing wave gets stuck in a preferred phase, thus locking the frequency of each beam to each other rather than responding to gradual rotation. Forced dithering can largely overcome this problem. The ring laser cavity is rotated clockwise and anti-clockwise about its axis using a mechanical

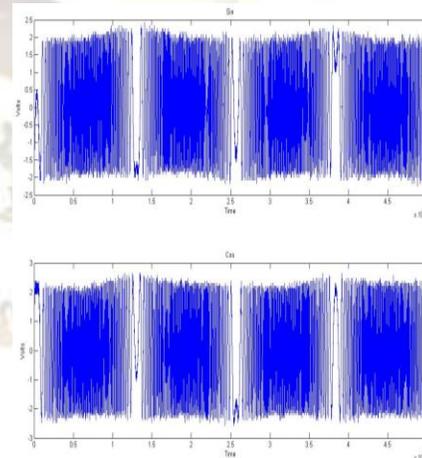


Figure 6: The RLG output

The clock signal is 10KHz with respect to clock signal square wave is generated. The QC-delay is the quarter cycle delay means the square wave is delayed for the quarter cycle. The strobe signal is twice the square wave. RLG model having the standard equations from that equations are optimized and developed code and implemented in LABview. The filtered output is given to the comparator. The square wave and output of comparator is XORed. If the output of the XOR is 0, the control counter is decremented. If the XOR is 1, then the control counter is incremented. If the QC-delay is 0 then the dither counter is incremented and QC-delay is 1 then the dither counter is decremented. The dither counter and control counter are inversely proportional. The algorithm is implemented for digital module and developed in FPGA. The filtered output of RLG are implemented in LABview. Interfacing is to be done between the NI LABview card and FPGA development kit.

## VI. CONCLUSION

Ring Laser Gyro (RLG) is used to sense angular information accurately and precisely. RLG mainly depends on the path length, intensity and

dithering.If path length changes there will be change in the intensity.By using RLG model equations,the sine and cosine signals are obtained.The algorithm is implemented .Interfacing is done between the NI LABview card and FPGA development kit.

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