

Ring Laser Gyroscope for accurate angle metrology

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Abstract—An apparatus for high precision angle metrology, based on a mid-scale ring laser gyroscope, is in development at the Italian Metrologic Research Institute (INRIM). The aim is to build a portable instrument with an accuracy in the range of some tens nanoradians.

Keywords—Ring laser Gyroscopes; angle metrology

I. INTRODUCTION

Ring laser gyroscopes (RLG) are the most sensitive and accurate instruments for the measurement of angular speed. The instrument is basically a gas laser built in a circular optical cavity where two counter propagating waves build up, creating a stationary wave. A light detector, embedded in the system, measures the intensity of the interference signal. Because of the invariance of speed of light c , the stationary wave is fixed in the inertial frame, so, when the laser is rotated (e.g. because of the Earth rotation) an oscillating interference signal is observed between the two waves, which frequency is proportional to the inertial rotational speed (Sagnac effect). RLG sensitivity (i.e. the relationship between the frequency and the angular speed) is dependent on the laser wavelength and the ring geometry.

Since the invention of the laser in the sixties small RLs (decimeter scale) are commonly used as gyroscopes for navigation of aircrafts, ships and submarines. RLs have progressively substituted the classical mechanical rotating gyroscopes being more robust and accurate.

II. ANGLE METROLOGY

Accurate measurement of angles (down to the nano-radian level) is a fundamental field of metrology, finding application in precision mechanical industry, geodetic measurements, astronomy and experimental physics. The angular scale is realised by subdividing the circle into a number of equal intervals, in fact implemented with the circular grating of angle encoders. Technological progress achieved in the last decades has allowed tremendous improvement in the encoder performances: nano-radian resolution have been achieved, but the accuracy is limited by technological factors to the microradian level. Calibration of such instruments is today an open issue of angle metrology.

In the eighties small RLGs have been engineered to be placed on a continuously rotating table capable of precisely impose a 2π revolution, so that the scale factor of the RLG can be accurately determined without a priori knowledge of the geometry of the instrument. This self-calibration property allows small RLGs to be used as angular standards in fact

acting as an ideal angular encoder. Opposite to angle encoders, RLGs have high intrinsic accuracy, since the calibration is based on a physical property, but the resolution is limited by quantum noise of the detection system. Integrating a small RLG with an optical angle sensor an accuracy near to $0.01''$ (50 nrad) has been achieved [1].

Larger RLs can have better resolution. Large RLs (several meters scale) are used for the measurement of Earth rotation rate for geodesy and seismology researches [2,3]. Recently an experiment for the measurement of the relativistic Lense-Thirring effect based on a large RLG (GINGER project) has been proposed with a required accuracy better than 10^{-8} [4].

We present here our project that aims to the realization of a mid-scale RLG (near 1 m), with a lightweight and stiff structure, made from carbon-reinforced carbon fibre (carbon-carbon) or syntherized silicon carbide so that it can be easily installed on a rotating platform, and as well easily transportable. The larger dimension will increase the instrumental sensitivity and the use of supermirrors with more than 99.999% of reflectivity will reduce the mirror back-scattering that might eventually induce non-linearity in the Sagnac signal. A precision autocollimator will allow the self-calibration procedure whenever necessary.

Such instrument will bring to the implementation of an extremely accurate rotational standard to be used for the calibration of the best angular measurement instrument, which resolution today is well beyond the traceability capabilities of most national metrology institutes. Further, the demonstration of a self-calibration concept will possibly lead to the design of a larger rotating RLG for geodetic and relativistic experiments, free from the need of extremely difficult dimensional measurements.

The RL will be used at INRIM as a novel and independent instrument for the calibration of highest level angular encoders and for the validation of novel measuring methods. The instrument will be circulated amongst main Metrology Institutes as a transfer standard.

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