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Nuclear and Particle Physics Proceedings 291–293 (2017) 140–145

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The GINGER Project

A. Di Virgilio[a], J. Belfi[a], F. Bosi[a], F. Morsani[a], G. Terreni[a], N. Beverini[b], G. Carelli[b], U. Giacomelli[b], E. Maccioni[b], A. Ortolan[c], A. Porzio[d], C. Altucci[e], R. Velotta[e], A. Donazzan[f], G. Naletto[f], D. Cuccato[f], A. Beghi[f], M.G. Pelizzo[g], M.L. Ruggiero[h], A. Tartaglia[h], G. De Luca[i], G. Saccorotti[j]

[a]*INFN- Sezione di Pisa, 56124 Pisa, Italy*
[b]*Univ. of Pisa, Phys. Dep., 56124 Pisa, Italy*
[c] *Laboratori Nazionali di Legnaro, 35020 Legnaro (PD), Italy*
[d]*CNR-SPIN, and Sez. INFN of Napoli, 80126 Napoli, Italy*
[e]*Dep. of Physics, University of Napoli, and INFN Sezione di Napoli, 80126 Napoli, Italy*
[f]*Department of Information Engineering, University of Padova, and INFN Sez. of Padova, Padova, Italy*
[g]*CNR-IFN Sezione di Padova, 35131 Padova, Italy*
[h]*Group. of Relativ. and Gravit., Politecnico of Torino, and INFN sez. of Torino, 10129 Torino, Italy*
[i]*INGV sez. of L'Aquila, L'Aquila, Italy*
[j] *INGV, Sez. of Pisa, 56124 Pisa, Italy*

Abstract

GINGER (Gyroscopes IN General Relativity) is a project aiming at measuring the Lense-Thirring effect,, at 1% level, with an experiment on earth. It is based on an array of ring-lasers, which are the most sensitive inertial sensors to measure the rotation rate of the Earth. The GINGER project is still under discussion; the experiment G-GranSasso is an *R&D* experiment financed by INFN Group II, it is studying the key points of GINGER and at the same time developing prototypes. In the following the signal coming out of a ring-laser and the present sensitivity are described.The prototypes GP2 and GINGERino and the preliminary results are reported. This project is inter-disciplinary since ring-lasers provide informations for the fast variation of the earth rotation rate, they are used for the rotational seismology and for top sensitivity angle metrology.

Keywords: Gyroscope, Sagnac Effect, Gravitomagnetism, Rotational Seismology, Earth rotation rate

1. Introduction

Ring Lasers Gyroscopes (RL) are top sensitivity devices widely used for measuring absolute rotation rates, exploiting the Sagnac effect. They are very reliable instruments, with extended bandwidth and very high duty cycle. Small size RLs are used for inertial navigation. The sensitivity increases with size. The most advanced RLs, devices with the area of tens of square meters, are used in seismology (rotational seismology), and in the geodetic community are considered the instruments able to measure the fast variations of the earth rotation rate (daily and sub-daily). The signal of a RL based on earth is proportional to the projection in the ring axis direction of the vector sum of the rotation rate of the planet, $\vec{\Omega}_\oplus$, plus the local rotation rate of the device, $\vec{\Omega}_l$. When the effects of non-Newtonian gravity are included an additional contribution appears; let us call it $\vec{\Omega}_{gr}$. Following General Relativity (GR), $\vec{\Omega}_{gr}$, at the highest orders, is in turn the sum of two contributions: the Lense-Thirring drag term $\vec{\Omega}_{LT}$ and de Sitter geodetic precession $\vec{\Omega}_{dS}$. These GR terms have modulus of the order $\sim 10^{-14}$ rad/s, nine orders of magnitude below the earth rotation rate. It is usually assumed that $\vec{\Omega}_l$, in an earth based laboratory is either negligible, with averaged value zero, or in case, could be modelled by other means. The present best sensitivity of a RL is $\sim 10^{-13}$ rad/s in one day of integration time [1], not far from the threshold to be crossed in order to detect the GR terms. The purpose

https://doi.org/10.1016/j.nuclphysbps.2017.06.028

of GINGER (Gyroscopes IN GEneral Relativity) is to measure the GR components of the gravitational field of the earth at 1% accuracy level, by means of an array of ring-lasers [2]. The first proposal based on an octahedral configuration [2] has been presented. The three-dimensional array would permit to reconstruct the modulus of the total angular rotation vector in the laboratory. The GR terms in this scheme would be evaluated by subtracting the earth rotation rate measured independently by the international system IERS ($\vec{\Omega}_{IERS}$). So far the gravitomagnetic field of the earth has been measured by space experiments, being the present accuracy limit $\sim$ 5%[5, 6]. The experimental objective of measuring Ω_{LT} down to 1%, is still challenging. GINGER would provide *the first measurement* of the General Relativistic features of the gravitational field, on the surface of the earth (not considering the gravitational redshift). Though not in free fall condition, it would be a direct local measurement independent from the global distribution of the gravitational field; not an average value, as in the case of the space experiments. The LenseThirring field depends on the latitude, and alternative theories predict different behaviour with the latitude.
At the moment the experimental set-up for the GINGER proposal is under discussion. Matter in discussion is if the 1% goal for the LenseThirring effect is really feasible, and if it is possible to proceed in steps with improved sensitivity and accuracy. As well different schemes are under discussion.
In the following the signal given by a ring-laser, the experimental work, and the main results of the two prototypes RLs GINGERino and GP2 will be shortly described.

2. Generalities

The RL is a laser with a ring optical cavity, where two counter-propagating modes circulate; the signal is the beat note in between the two beams coming out of the cavity, see fig. 1. Each RL is described by its scale factor S and its area versor $\vec{n}$, the response of the RL is the beat frequency f proportional to the scalar product between the total angular rotation vector Ω_T and the vector area of the ring optical cavity $f = S(\vec{\Omega}_T) \cdot \vec{n}$. The scale factor S depends on the geometry of the ring, $S = \frac{4A}{\lambda P}$, where A is the area and P the perimeter of the ring, λ is the wavelength of the light of the Laser. With an appropriate construction and location of the apparatus and for long enough integration time we may assume $< \Omega_l >$ to be negligible (or modellizable) even with respect to the GR terms, so that, in the framework of General Relativity (GR), we write $f = S(\vec{\Omega}_\oplus + \vec{\Omega}_{LT} + \vec{\Omega}_{dS}) \cdot \vec{n}$. For a detailed description of the RL signal with GR terms, interested readers are can see [2, 3, 4]. This general formulation of the RL frequency has been deduced assuming GR and the consequence is that the beat note expected from a RL contains three actual or effective rotations. The corresponding three axial vectors are coplanar, and contained in the meridian plane. The mutual orientations are fixed by the theory and depend on the latitude, see fig. 2.

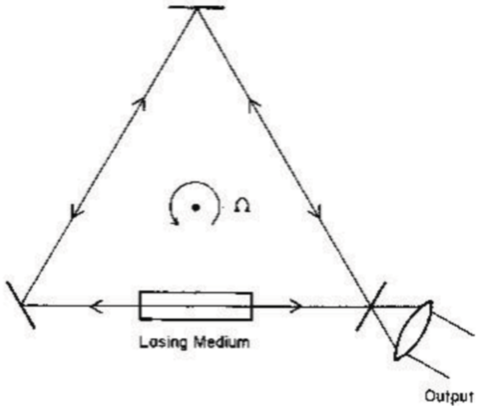

Figure 1: Typical RL scheme with rotation $\vec{\Omega}$, in this case the RL cavity is defined by three mirrors and has a triangular shape. Other shapes are feasible.

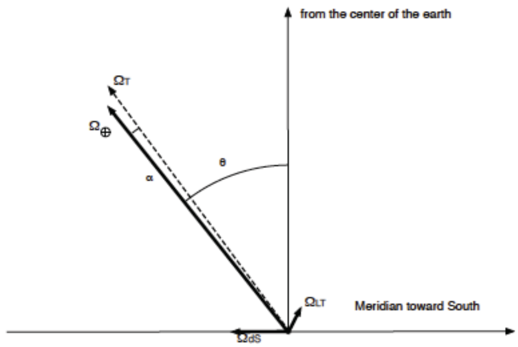

Figure 2: The three axial vectors $\vec{\Omega}_\oplus$, $\vec{\Omega}_{LT}$, and $\vec{\Omega}_{dS}$ are shown, with the relative orientation at the latitude of the underground laboratory of GranSasso (LNGS), following General Relativity. The angle α and Ω_T (dashed line) are shown as well. The graph is not on scale, it gives a pictorial view of the relative orientations of the different components, in the reality the modulus of $\vec{\Omega}_\oplus$ is 9 orders on magnitude bigger than the GR terms, and the angle α is $\sim 10^{-9}$ *rad*.

Fig. 2 shows the relative orientation of the relevant vectors at the latitude of LNGS. Each RL measures the