Possible measurable effects of light propagating in electromagnetized vacuum, as predicted by a scalar tensor theory of gravitation

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Abstract

The effect of static electromagnetic fields on the propagation of light is analyzed in the context of a particular class of scalar-tensor gravitational theories. It is found that for appropriate field configurations and light polarization, anomalous amplitude variations of the light as it propagates in either a magnetized or electrified vacuum are strong enough to be detectable in relatively simple laboratory experiments.

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1 Introduction

Scalar-tensor (ST) gravitational theories are the most firm candidates for extensions of General Relativity (GR). A great part of their interest comes from the fact that they are induced naturally in the reduction to four dimensions of string and Kaluza-Klein models, resulting mostly in the form of a Brans-Dicke (BD) type of ST theory, often involving also non-minimal coupling to matter, leading to the so called fifth force. It is also interesting that ST theories are shown to be mathematically equivalent to theories with action depending non-linearly on the Ricci scalar, the so called \( f(R) \) theories. Finally, ST theories are possibly the simplest extension of GR that could accommodate cosmological issues as inflation and universe-expansion acceleration, as well as possible space-time variation of fundamental constants.

On the other hand, observational and experimental evidence puts strong limits to the observable effects of a possible scalar field. For example, in the case of a massless scalar the BD parameter \( \omega \) is constrained by precise Solar-System experiments to be a large number \( \omega > 4 \times 10^4 \). In this way, ST gravity phenomenology appears to be very similar to that of GR, thus putting strong limits to possible experimental verifications. There is however a very interesting extension of ST gravity put forward by Mbelekb and Lachièze-Rey, which could allow electromagnetic (EM) fields to modify the space-time metric far more strongly than predicted by GR and standard ST theories. The theory was applied in cosmological and galactic contexts, and in it was used to explain the discordancy in the measurements of Newton gravitational constant as due to the effect of the Earth’s magnetic field. The key new element of that theory is an additional, external scalar field \( \psi \), minimally coupled to gravity. In it was shown that a general ST theory that includes an external field \( \psi \) with the mentioned characteristics, and with the magnitude of the coupling derived in, can explain the unusual forces on asymmetric resonant cavities recently reported.
2 Scalar-tensor theory

We will consider the weak-field limit of a ST theory with action given by (SI units are used)

\[
S = -\frac{c^3}{16\pi G_0} \int \sqrt{-g} \phi R d\Omega + \frac{c^3}{16\pi G_0} \int \sqrt{-g} \frac{\omega(\phi)}{\phi} \nabla^\nu \phi \nabla_\nu \phi d\Omega \\
+ \frac{c^3}{16\pi G_0} \int \sqrt{-g} \left[ \frac{1}{2} \nabla^\nu \psi \nabla_\nu \psi - U(\psi) - J \right] d\Omega \\
- \frac{\varepsilon_0 c}{4} \int \sqrt{-g} \lambda(\phi) F_{\mu\nu} F^{\mu\nu} d\Omega - \frac{1}{c} \int \sqrt{-g} j^\nu A_\nu d\Omega \\
+ \frac{1}{c} \int \mathcal{L}_{\text{mat}} d\Omega. \tag{1}
\]

In (1) the internal, non-dimensional scalar field is $\phi$, while the external scalar field is $\psi$. These fields have vacuum expectation values (VEV) $\phi_0 = 1$ and $\psi_0$, respectively. $G_0$ represents Newton gravitational constant, $c$ is the velocity of light in vacuum, and $\varepsilon_0$ is the vacuum permittivity. $\mathcal{L}_{\text{mat}}$ is the lagrangian density of matter. The other symbols are also conventional, $R$ is the Ricci scalar, and $g$ the determinant of the metric tensor $g_{\mu\nu}$. The BD parameter $\omega(\phi)$ is considered a function of $\phi$, as it usually results in the reduction to four dimensions of multidimensional theories\[2\]. The function $\lambda(\phi)$ in the term of the action of the EM field is of the type appearing in Bekenstein’s theory and other effective theories\[9\]. The EM tensor is $F_{\mu\nu} = \nabla_\mu A_\nu - \nabla_\nu A_\mu$, given in terms of the EM quadri-vector $A_\nu$, with sources given by the quadri-current $j^\nu$. $U$ and $J$ are, respectively, the potential and source of the field $\psi$. The source $J$ contains contributions from the matter, EM field and the scalar $\phi$. The model for $J$ proposed in\[8\] is

\[
J = \beta_{\text{mat}}(\psi, \phi) \frac{8\pi G_0}{c^4} T^{\text{mat}} + \beta_{\text{EM}}(\psi, \phi) \frac{4\pi G_0 \varepsilon_0}{c^2} F_{\mu\nu} F^{\mu\nu}, \tag{2}
\]

where $T^{\text{mat}}$ is the trace of the energy-momentum tensor of matter,

\[
T^{\text{mat}}_{\mu\nu} = -\frac{2}{\sqrt{-g}} \frac{\delta \mathcal{L}_{\text{mat}}}{\delta g^{\mu\nu}}.
\]

Variation of (1) with respect to $g^{\mu\nu}$ results in ($T^{EM}_{\mu\nu}$ is the usual electromagnetic energy tensor, and $T^\phi_{\mu\nu}$ the energy tensor associated to the scalar field $\phi$).
\[ \phi \left( R_{\mu \nu} - \frac{1}{2} R g_{\mu \nu} \right) = \frac{8\pi G_0}{c^4} \left[ \lambda (\phi) T_{\mu \nu}^{EM} + T_{\mu \nu}^{mat} \right] + \frac{\phi}{2} \left( \nabla_\mu \psi \nabla_\nu \psi - \frac{1}{2} \nabla_\gamma \psi \nabla_\gamma \psi g_{\mu \nu} \right) + \frac{\phi}{2} (U + J\psi) g_{\mu \nu}. \] (3)

Variation with respect to \( \phi \) gives

\[ \phi R + 2\omega \nabla^\nu \nabla_\nu \phi = \left( \frac{\omega}{\phi} - \frac{d\omega}{d\phi} \right) \nabla^\nu \phi \nabla_\nu \phi - \frac{4\pi G_0 \varepsilon_0}{c^2} \phi \frac{d\lambda}{d\phi} F_{\mu \nu} F^{\mu \nu} \]

\[ - \frac{\partial J}{\partial \phi} \psi \phi + \phi \left[ \frac{1}{2} \nabla^\nu \psi \nabla_\nu \psi - U (\psi) - J \psi \right], \]

which can be rewritten, using the contraction of (3) with \( g_{\mu \nu} \) to replace \( R \), as

\[ (2\omega + 3) \nabla^\nu \nabla_\nu \phi = -\frac{d\omega}{d\phi} \nabla^\nu \phi \nabla_\nu \phi - \frac{4\pi G_0 \varepsilon_0}{c^2} \phi \frac{d\lambda}{d\phi} F_{\mu \nu} F^{\mu \nu} + \frac{8\pi G_0}{c^4} T^{mat} \]

\[ + \phi \left[ \frac{1}{2} \nabla^\nu \psi \nabla_\nu \psi - U (\psi) - J \psi \right] - \frac{\partial J}{\partial \phi} \psi \phi, \] (4)

where it was used that \( T^{EM} = T^{EM}_{\mu \nu} g^{\mu \nu} = 0 \).

The non-homogeneous Maxwell equations are obtained by varying (1) with respect to \( A_\nu \),

\[ \nabla_\mu \left\{ \lambda (\phi) F^{\mu \nu} \right\} = \mu_0 j^\nu. \] (5)

with \( \mu_0 \) the vacuum permeability.

Finally, the variation with respect to \( \psi \) results in

\[ \nabla^\nu \nabla_\nu \psi + \frac{1}{\phi} \nabla^\nu \psi \nabla_\nu \phi = -\frac{\partial U}{\partial \psi} - J - \frac{\partial J}{\partial \psi} \psi + \frac{\beta}{\phi} \frac{8\pi G_0}{c^4} T^{mat}. \] (6)

Having included \( G_0 \), it is understood that \( \phi \) takes values around its vacuum expectation value (VEV) \( \phi_0 = 1 \). The scalar \( \psi \) is also dimensionless and of VEV \( \psi_0 \).

These equations can be approximated in the weak-field limit keeping only the lowest significant order in the perturbations \( h_{\mu \nu} \) of the metric \( g_{\mu \nu} \) about
the Minkowski metric $\eta_{\mu\nu}$, with signature (1,-1,-1,-1), and of the scalar fields about their VEV $\phi_0$ and $\psi_0$

$$-\eta^{\gamma\delta}\partial_{\gamma\delta}\overline{h}_{\mu\nu} = 2 \left( \partial_{\mu\nu}\phi - \eta^{\gamma\delta}\partial_{\gamma\delta}\phi\eta_{\mu\nu} \right),$$

$$\partial_{\gamma}\overline{h}_{\gamma} = 0,$$

$$\left(2\omega_0 + 3\right) \eta^{\gamma\delta}\partial_{\gamma\delta}\phi = - \frac{\partial J}{\partial\phi} \bigg|_{\phi_0,\psi_0} \psi_0,$$

$$\partial_{\nu}F_{\mu\nu} = -\mu_0 \left[ 1 - \chi'_0 (\phi - \phi_0) \right] j_\mu - F_{\mu\nu} \partial_\nu (\chi'_0 \phi - \overline{h}/2)$$

$$\eta^{\gamma\delta}\partial_{\gamma\delta}\psi = - \frac{\partial J}{\partial\psi} \bigg|_{\phi_0,\psi_0} \psi_0,$$

where $\omega_0 = \omega(\phi_0)$, $\chi'_0 \equiv d\lambda/d\phi|_{\phi_0}$, and $\overline{h}_{\mu\nu} \equiv h_{\mu\nu} - \frac{1}{2}h\eta_{\mu\nu}$,

with $\overline{h} = \eta^{\mu\nu}\overline{h}_{\mu\nu}$. In these equations only the EM sources were included, the effect of the matter terms either being negligible or included in the local gravitational field.

Using the source $J$ given in (2), with only the EM terms we finally obtain the complete set of equations for the EM field (making explicit the electric and magnetic field vectors $E$ and $B$, respectively)

$$\Box \Theta = \kappa \left( B^2 - E^2/c^2 \right),$$

$$\nabla \cdot E = \frac{\tilde{\rho}}{\varepsilon_0} - \nabla \Theta \cdot E,$$

$$\nabla \times E = -\frac{\partial B}{\partial t}, \quad \nabla \cdot B = 0,$$

$$\nabla \times B = \mu_0 \tilde{J} + \frac{1}{c^2} \frac{\partial E}{\partial t} + \frac{1}{c^2} \frac{\partial \Theta}{\partial t} E - \nabla \Theta \times B,$$

where the auxiliary field $\Theta$ is defined as $\Theta \equiv \chi'_0 \phi - \overline{h}/2$, and the electromagnetic sources were redefined as $\tilde{j}_\mu \equiv [1 - \chi'_0 (\phi - \phi_0)] j_\mu$. The constant $\kappa$ is

$$\kappa = \frac{8\pi G_0 \varepsilon_0}{\left(2\omega_0 + 3\right) c^2} \psi_0 \frac{\partial \beta_{EM}}{\partial \phi} \bigg|_{\phi_0,\psi_0},$$

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which, according to [8], has a value of order
\[ \kappa \simeq 5 \times 10^{-8} \frac{A^2}{N^2}. \] 

(13)

To study the propagation of electromagnetic waves we consider the case of a vacuum with uniform and static electric and magnetic fields \( E_0 \) and \( B_0 \), so that one can linearize the system (12) in the perturbations as

\[ \nabla \cdot \delta E = -\nabla \Theta \cdot E_0 - \nabla \Theta_0 \cdot \delta E, \] 
(14a)

\[ \nabla \times \delta E = - \frac{\partial \delta B}{\partial t}, \quad \nabla \cdot \delta B = 0, \] 
(14b)

\[ \nabla \times \delta B = \frac{1}{c^2} \frac{\partial \delta E}{\partial t} + \frac{1}{c^2} \frac{\partial \delta \Theta}{\partial t} E_0 - \nabla \delta \Theta \times B_0 - \nabla \Theta_0 \times \delta B, \] 
(14c)

\[ \nabla^2 \Theta_0 = -\kappa \left( \frac{E_0^2}{c^2} \right), \] 
(14d)

\[ \Box \delta \Theta = 2\kappa \left( B_0 \cdot \delta B - E_0 \cdot \delta E / c^2 \right). \] 
(14e)

Starting with this system we consider now different simple configurations.

2.1 Case \( E_0 = 0 \)

For the case without zero order electric field, \( E_0 = 0 \), and perturbations \( \delta E, \delta B, \delta \Theta \sim \exp \left( i \kappa \cdot x - \omega t \right) \) one has from (14)

\[ k \cdot \delta E = i \nabla \Theta_0 \cdot \delta E, \] 

\[ k \times \delta E = \omega \delta B, \] 

\[ k \times \delta B = - \frac{\omega}{c^2} \delta E - k \times B_0 \delta \Theta + i \nabla \Theta_0 \times \delta B, \] 

\[ \left( k^2 - \omega^2 / c^2 \right) \delta \Theta = 2\kappa B_0 \cdot \delta B. \]

For propagation along the magnetic field, \( B_0 \parallel k \), with \( \nabla \Theta_0 \perp k \), one has

\[ \delta E_\parallel = i \nabla \Theta_0 \cdot \delta E_\perp / k, \] 

\[ \delta E_\perp = - \frac{\omega}{k^2} k \times \delta B, \] 

\[ k \times \delta B = - \frac{\omega}{c^2} \left( \delta E_\perp + \delta E_\parallel \frac{k}{k} \right) + i \nabla \Theta_0 \times \delta B, \]
replacement of the first two equations in the last results in

$$\left(1 - \frac{\omega^2}{k^2c^2}\right) k \times \delta B + i \left[ \nabla \Theta_0 \times \delta B - \frac{\omega^2}{k^4c^2} \nabla \Theta_0 \cdot (k \times \delta B) k \right] = 0.$$  

It is easy to see that the last equation can only be satisfied if

$$\omega^2 = k^2c^2,$$

the usual dispersion relation for EM waves in vacuum. For the kind of propagation considered we thus have the standard plane EM wave for $\delta E_\perp$ and $\delta B$, with only the addition of a longitudinal component of amplitude

$$\delta E_a = i \nabla \Theta_0 \cdot \delta E_\perp / k.$$  

We consider now propagation perpendicular to the zero order field. Taking $E_0 = 0$, $B_0 = B_0 e_z$, $\nabla \Theta_0 = a e_x$, $k = k_x e_x + k_y e_y$, the general system (14) can be reduced to

$$\begin{align*}
(\omega^2 - k^2c^2) \delta B_z + iak_x c^2 \delta B_z &= k^2c^2B_0 \delta \Theta, \\
(\omega^2 - k^2c^2) \delta B_x - iak_y c^2 \delta B_y &= 0, \\
(\omega^2 - k^2c^2) \delta B_y + iak_x c^2 \delta B_y &= 0, \\
(k^2c^2 - \omega^2) \delta \Theta &= 2\kappa c^2 B_0 \delta B_z.
\end{align*}$$

In the case $\delta B_z = 0$, this system has non-trivial solution only for the dispersion relation

$$\omega^2 = k^2c^2 + iak_x c^2 = 0,$$

from which, $\omega = kc + i\gamma$, with $(\cos \theta = k_x / k)$

$$\gamma = -\frac{ac \cos \theta}{2}. \quad (15)$$

In the case $\delta B_z \neq 0$, one also has $\omega = kc + i\gamma$, with

$$\gamma = -\frac{1}{2} \left[ \pm \sqrt{2\kappa c^2 B_0^2 + \left(\frac{ac \cos \theta}{2}\right)^2 + \frac{ac \cos \theta}{2}} \right]. \quad (16)$$

Using the equation for $\Theta_0$ in (14) one can estimate that

$$a = |\nabla \Theta_0| \sim \kappa B_0^2 L,$$
with $L$ a characteristic length of the system, so that the $a$ terms can be neglected in the expression (16), to obtain

$$\gamma = \pm \sqrt{\frac{\kappa}{2}} B_0 c,$$

(17)
much larger that in the case $\delta B_z = 0$.

### 2.2 Case $B_0 = 0$

For the case without zero order magnetic field, $B_0 = 0$, and perturbations $\delta E, \delta B, \delta \Theta \sim \exp i (k \cdot x - \omega t)$ one has

\begin{align*}
    k \cdot \delta E &= -k \cdot E_0 \delta \Theta + i \nabla \Theta_0 \cdot \delta E, \\
    k \times \delta E &= \omega \delta B, \\
    k \times \delta B &= -\frac{\omega}{c^2} \delta E - \frac{\omega}{c^2} E_0 \delta \Theta + i \nabla \Theta_0 \times \delta B, \\
    (k^2 c^2 - \omega^2) \delta \Theta &= -2 \kappa E_0 \cdot \delta E. 
\end{align*}

(18)

For propagation along the electric field, $E_0 \parallel k$, with $\nabla \Theta_0 \perp k$, one then has

\begin{align*}
    \delta \Theta &= \frac{(i \nabla \Theta_0 - k)}{k \cdot E_0} \cdot \delta E, \\
    (k - i \nabla \Theta_0) \times (k \times \delta E) &= -\frac{\omega^2}{c^2} \delta E + \frac{\omega^2}{c^2} E_0 \frac{(k - i \nabla \Theta_0)}{k \cdot E_0} \cdot \delta E.
\end{align*}

Again, it is easy to see that the last relation is satisfied, for arbitrary longitudinal component $\delta E_\parallel$, only if $\omega^2 = k^2 c^2$, with the standard plane EM wave relations for $\delta E_\perp$ and $\delta B$; while the longitudinal component $\delta E_\parallel$ must be zero in order to satisfy (18). In this way, the standard plane EM wave is the only solution in this case.

For propagation perpendicular to the zero order field, one has now $B_0 = 0$, $E_0 = E_0 e_z$, $\nabla \Theta_0 = a e_x$, $k = k_x e_x + k_y e_y$, and the general system (14) can
be reduced to

\[
(\omega^2 - k^2c^2) \delta B_z + iak_x c^2 \delta B_z = 0,
\]

\[
(\omega^2 - k^2c^2) \delta B_x - iak_y c^2 \delta B_y = \frac{2\kappa \omega^2 E_0^2 k_y}{k^2 (\omega^2 - k^2c^2)} (k_x \delta B_y - k_y \delta B_x),
\]

\[
(\omega^2 - k^2c^2) \delta B_y + iak_x c^2 \delta B_y = -\frac{2\kappa \omega^2 E_0^2 k_x}{k^2 (\omega^2 - k^2c^2)} (k_x \delta B_y - k_y \delta B_x).
\]

If \(\delta B_z \neq 0\), one has \(\omega = kc + i\gamma\), with the same value \((15)\) as in the case of \(E_0 = 0\), while if \(\delta B_z = 0\) one has the much larger value

\[
\gamma = \pm \sqrt{\frac{\kappa}{2} E_0}.
\]  

(19)

2.3 Experimental possibilities

From the previous subsections it is seen that the more noticeable effects are obtained for propagation perpendicular to the zero order fields, with the appropriate polarization of the wave in each case. Moreover, comparing (19) with (17) it is clear that, from a practical point of view, magnetic fields are preferable. In any case, when the beam traverses a length \(\Delta L\), the relative variation of the amplitude \(A\) of any field is given by

\[
\frac{\Delta A}{A} = \exp \left( \frac{\gamma \Delta L}{c} \right).
\]

(20)

For the case of a magnetic field of 1T, with \(\delta B_z \neq 0\), one can thus estimate from (13) and (17)

\[
\frac{\gamma}{c} \sim 10^{-4} m^{-1}.
\]

Although this effect is relatively large, there is the problem that both, growing and decreasing modes are always present, so that a wave entering the region with the static magnetic field results in a superposition of both modes, and so the variation of amplitude of the growing mode cancels with that of the decreasing mode at first order in \(\gamma \Delta L/c\), and the effect is only observable at second order, much hindering the experiment.

There is however a further possibility. It was argued in\([11]\) that, in order for the theory to be consistent with the lack of strong gravitational effects due to the magnetic field of the Earth, the non-linear terms in Eqs. (4) and
should come into play. In this way, for the case of a static magnetic field outside its sources one can write $B = \nabla \Psi$, with $\nabla^2 \Psi = 0$, so that equations (1) and (3) for the static case are

\[(2\omega_0 + 3) \nabla^2 \phi + \frac{d\omega}{d\phi}_{\phi_0, \psi_0} \nabla \phi \cdot \nabla \phi \propto B^2 = \nabla \Psi \cdot \nabla \Psi,
\]

\[\nabla^2 \psi + \nabla \phi \cdot \nabla \psi \propto B^2 = \nabla \Psi \cdot \nabla \Psi,
\]

which have the exact solutions $\nabla \phi \propto \nabla \psi \propto \nabla \Psi$, so that $\nabla^2 \phi = \nabla^2 \psi = 0$, thus largely reducing the source of the gravitational force. This solution for the case of the Earth’s magnetic field is compatible with the proposal in [8], in which the solution with $\nabla^2 \phi \neq 0$ was used, if

\[d\omega/d\phi|_{\phi_0, \psi_0} \sim -(2\omega_0 + 3).
\]

With these considerations, the field $\Theta_0$ is simply given by

\[\nabla \Theta_0 = \lambda B_0,
\]

with $\lambda \simeq \sqrt{\chi}$. In this case the system (14) can be written as (with $E_0 = 0$)

\[\nabla \cdot \delta E = -\lambda B_0 \cdot \delta E,
\]

\[\nabla \times \delta E = -\frac{\partial \delta B}{\partial t}, \quad \nabla \cdot \delta B = 0,
\]

\[\nabla \times \delta B = \frac{1}{c^2} \frac{\partial \delta E}{\partial t} - \lambda B_0 \times \delta B,
\]

where the term with $\delta \Theta$ can be neglected as it is small, since from (14) one can estimate that

\[\frac{\nabla \delta \Theta \times B_0}{\nabla \Theta_0 \times \delta B} \sim \sqrt{\chi}B_0L,
\]

with $L$ a characteristic length of field variation.

Proceeding as before one has

\[k \cdot \delta E = i\lambda B_0 \cdot \delta E,
\]

\[k \times (k \times \delta E) = -\frac{\omega}{c^2} \delta E + i\lambda B_0 \times (k \times \delta E).
\]

For propagation perpendicular to $B_0$ one has

\[\left(\frac{\omega^2}{c^2} - k^2\right) \delta E_\perp + \frac{\omega^2}{kc^2} \delta E \parallel k = i\lambda B_0 \delta E_\perp \cos \alpha k,
\]

\[k \delta E_\parallel = i\lambda B_0 \delta E_\perp \cos \alpha,
\]

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where $\alpha$ is the angle between $B_0$ and $\delta E_\perp$. As a result the dispersion relation is that of a normal EM wave, $\omega = kc$, and the only anomalous effect is the presence of a small longitudinal component of the electric field.

In the case of propagation along $B_0$ one has

$$\left(\frac{\omega^2}{c^2} - k^2\right) \delta E_\perp = -i\lambda k B_0 \delta E_\perp,$$
$$k \delta E_\parallel = i\lambda B_0 \delta E_\parallel,$$

so that $E_\parallel = 0$, and $\omega = kc + i\gamma$, with

$$\gamma = -\frac{\lambda B_0 c}{2}.$$ 

This effect is similar in magnitude to that in (17), but with the advantage that only one sign is possible, so that there are not coexisting growing and decaying modes, and the growth (or decay) could be observed at first order.

3 Table-top experiments with optical fibers

Due to the relevance of first order effects in the propagation of EM waves, it seems plausible that the use of simple and readily available nowadays fiber optics would allow the verification of the theoretical results of the previous section. Especially, the last result of subsection 2.3 shows a direct method for measuring the additional amplitude change caused by the propagation of a single mode inside an ordinary polymer fiber. Given the significance of separating between alternative extensions of general relativistic theories for modern cosmology we propose that such an experiment is of great importance due to its simplicity.

Specifically, our proposal is to get a sufficiently large fiber appropriately coiled which, with existing materials, can be made to easily reach a km of total distance for the propagating mode. By taking the logarithm of Eq (20) as $10 \log_{10}(\frac{A}{A_0})$, for the amplitude variation to be in dB units, we see that a magnetic field of 2 T would result in an amplitude variation of 1 dB in 1 km distance. It is possible to reduce such a distance by an order of magnitude only through a large magnetic field of about 10 T or more which can be produced in current NMR devices while use of superconducting elements could reach even higher values. Actually, recent reports from the NHMFL at
Los Alamos claim a 100 T machine is already operational [13]. At the moment we will only assume the strongest existing rare earth magnets like Boron-Niodymium for a tabletop experiment where sufficiently high accuracy power meters are available. The central idea is to detect the difference between measurement on the fiber coil, with and without the B field. Present day power meters have an accuracy noise threshold of about 0.1 dB. Fortunately, existing manufacturers may be able to provide bobbins totalling 25 km of fiber or more so that a measurement of 10 - 20 dB of additional amplitude variations is in principle possible.

Figure 1: Proposed configuration of the optical fiber and Helmholtz coils.

With respect to the fiber coiling process, one has to take into account that any angles introduced to the fiber material introduce additional attenuation to any propagating mode. Technical data for existing fiber materials suggest that there should be a certain curvature with angles small enough not to cause severe damping during normal propagation. This can be achieved with
a flattened coil frame like the one shown in Fig.1.

As we are not interested in all the engineering details of an actual experiment we only emphasize the main points where care must be taken using some simplified configurations. In the flattened fiber coil of Fig.1 care must be taken so that on the upper path the fiber is parallel to the direction of the external magnetic field. The return path, though, must be outside the region of influence or else the amplitude variation effect will be cancelled and no difference will be measured. For this reason we also made the flattened electromagnets shown in such a way that the homogenized flux of the applied B field will only affect the upper part of the fiber’s path. It is also possible to make up an homogeneous magnetic field using Neodymium magnets in a special configuration known as a cylindrical “Halbach Array” [14]. Such arrays have been in use for a long time in magnetic trains, very fast brushless motors and similar electrical engineering applications. In such a case, the upper or lower part of the flattened fiber coil should be put inside the region of homogeneous B flux of a Halbach cylinder.

4 Conclusions

We have here reported for the first time some new results on the possible gravitational influence on classical EM fields in scalar-tensor extensions of General Relativity. We also used the linearized version of the perturbed Maxwell equations to analyse the propagation of ordinary modes. The analysis led us to conclude the possibility of easy, low cost experiments with fiber optics that would allow the verification of the said theories. We believe that the present state of cosmology with the recurring acute problems of inflation and initial conditions, the CMB anisotropy as well as the dark matter and dark energy, fully justifies the continuation of the present research in more areas where evidence can be accumulated experimentally.

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