ThA2 **8:45am**

Electrostrictive nonlinearity in optical fiber deduced from Brillouin gain measurements

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The nonlinear refractive index has drawn considerable attention these past few years, because it may significantly perturbate long-range propagation of lightwaves in optical fibers. Two main origins to this nonlinearity have been identified:[1] nonresonant electronic nonlinearity and electrostriction. These contributions differently interact with light, so that it is of prime importance to quantify the relative importance of each contribution. Some recent works demonstrated that electrostriction may contribute more significantly than formerly expected[2] and a tentative quantification was even reported.[3]

On the other hand the electrostriction is the main driving mechanism of stimulated Brillouin scattering that is today quantatively very well described, because very accurate measurements of the Brillouin linear gain g_B have been recently obtained.[4] This paper shows that the electrostrictive contribution to the nonlinear refractive index n_2 may indeed be straightforwardly calculated from Brillouin gain measurements.

The Brillouin linear gain g_B is dependent on material properties and in particular on the electrostrictive coefficient $\gamma_e = \rho\partial\varepsilon/\partial\rho$, according to the following relation:[1]

$$g_B = \frac{2\pi\gamma_e^2}{c_0\varepsilon_0^2\lambda_0^2\rho\Delta\nu_B c_A n}$$

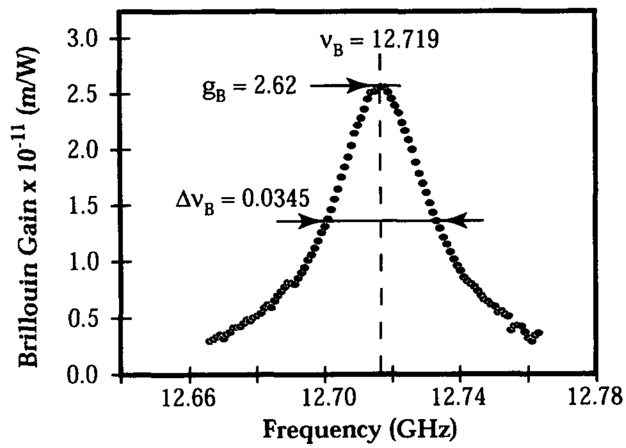
where c_0 is the vacuum light velocity, λ_0 the vacuum wavelength, ρ the fiber material density, $\Delta\nu_B$ the Brillouin FWHM linewidth, n the refractive index and c_A the fiber acoustic velocity that is directly deduced from the Brillouin Stokes shift $\nu_B = 2nc_A/\lambda_0$. The three parameters g_B, ν_B and $\Delta\nu_B$ fully characterize the Brillouin gain spectrum and were measured with a high accuracy,[4] as shown in Fig. 1. The electrostrictive coefficient γ_e may be easily calculated from the gain spectrum measurements, because the other material coefficients are well known.

The electrostrictive pressure is balanced by the medium compression, resulting in an increased density and thus a modified susceptibility:[1]

$$\Delta\chi = \frac{\Delta\varepsilon}{\varepsilon_0} = \frac{1}{2}\frac{C\gamma_e^2}{\varepsilon_0}\frac{|E|^2}{2}$$

where $C = \rho\partial p/\partial\rho$ is the medium compressibility and $|E|^2/2$ results from the time-averaging of the squared optical field E^2. The electrostriction generates a susceptibility change proportional to the optical intensity $I = (n\varepsilon_0 c_0/2)|E|^2$, that modifies the refractive index this way:

$$\Delta n = \frac{\partial n}{\partial\chi}\Delta\chi = \frac{\Delta\chi}{2n} = \frac{1}{4}\frac{C\gamma_e^2}{\varepsilon_0}|E|^2 = \frac{1}{4}\frac{C\gamma_e^2}{n^2\varepsilon_0^2 c_0} I$$



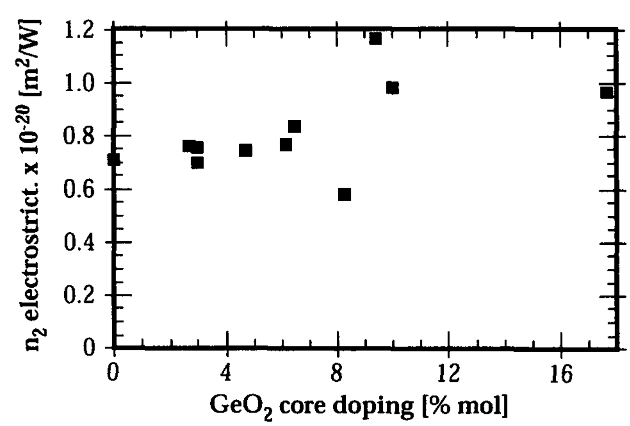
ThA2 Fig. 1. High-accuracy Brillouin gain spectrum measurement of a single-mode silica fiber performed at a 1319-nm wavelength, with the estimated value of the three characterizing parameters.

so that the electrostrictive nonlinear refractive index reads:

$$n_2^{elec} = \frac{C\gamma_e^2}{4n^2\varepsilon_0^2 c_0} = 0.7 \times 10^{-20}\ \frac{m^2}{W} \text{ for a standard single-mode fiber.}$$

Assuming a total nonlinear refractive index $n_2 = 2.96 \times 10^{-20}$ m^2/W the contribution of the electrostriction to the Kerr effect amounts to 23% at a 12–13 GHz frequency, corresponding to pulse width in the 20–30 ps range. This is much more in magnitude and in bandwidth than what was formerly suggested,[3] because the maximal calculated value of 16% was expected to rapidly vanish for pulse width narrower than 1 ns.

Figure 2 shows the electrostrictive contribution to the nonlinear refractive index deduced from Brillouin gain measurements for a wide bunch of fibers having different GeO_2 core doping concentration. The scattering of the results is most probably due to an unknown factor specific to stimulated Brillouin scattering: the overlapping degree between optical and acoustic guided modes. This factor is always smaller than unity, so that the electrostrictive contribution is at most underestimated using Brillouin gain measurements. The actual value should be close to 50% of the total nonlinear index, taking into account an estimation of the overlapping degree.



ThA2 Fig. 2. Calculated electrostrictive contribution to the nonlinear refractive index from Brillouin gain spectrum measured in single-mode fibers with different core doping.

1. R.W. Boyd, *Nonlinear Optics*, (Academic Press, San Diego, 1992), Ch. 4.
2. E. Dianov, A. Luchnikov, A. Pilipetskii, A. Starodumov, Opt. Lett. **15**, 314 (1990).
3. E.L. Buckland, R.W. Boyd, in *Optical Fiber Communication Conference*, Vol. 2 of 1996 OSA Technical Digest Series (Optical Society of America, Washington, D.C., 1996), pp. 224–225.
4. M. Niklès, K. Thévenaz, Ph. Robert, IEEE J. Lightwave Technol. **15**, (October 1997), *in press.*