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Evaluation of local birefringence along fibres using Brillouin analysis

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A novel method is proposed to measure the local birefringence in a standard fibre using the polarisation dependence of stimulated Brillouin scattering, in a non-destructive and simple way.

It has been demonstrated over the past few years that polarisation mode dispersion (PMD) may limit the ultimate data rate through an optical fibre. The basic reason for PMD is the presence of intrinsic or induced birefringence within the fibre. Measuring the local birefringence would thus provide key information to localize the fibre segments mainly contributing to PMD, so that an efficient action could be undertaken for cable upgrade. A simple solution based on Rayleigh reflectometry using polarized light, the so-called POTDR technique [1], has been proposed. For reasons related to light coherence, measurements using such a technique are often perturbated by interferometric noise or screened by chromatic dispersion.

We report here a novel method for local birefringence measurements based on the polarisation dependence of the stimulated Brillouin interaction. This method offers the key advantage to provide a signal very immune to noise. In addition it also unambiguously indicates if the birefringence beat length can be resolved by the spatial resolution of the instrument or is too short to be observed.

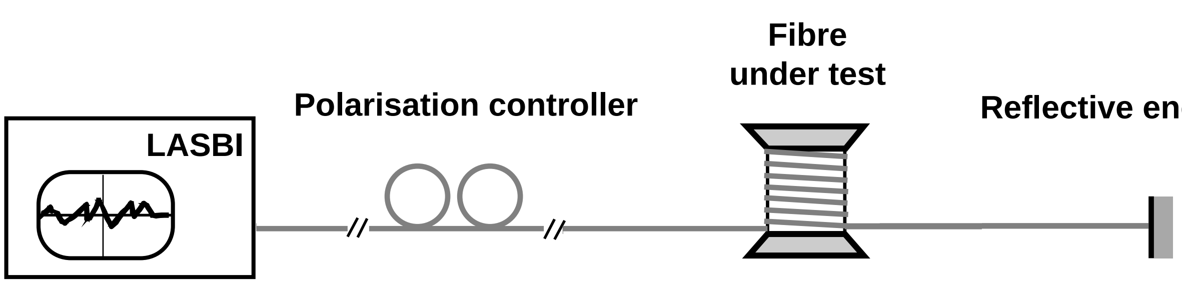

Fig. 1 *Experimental setup. The LASBI instrument measures the local Brillouin gain along the fibre that provides information about local polarisation.*

Fig. 1 shows the experimental configuration of this method. It basically relies on an instrument providing a local analysis of the stimulated Brillouin interaction (LASBI) [2, 3]. The instrument launches a CW lightwave, that is reflected at the far end of the fibre and then returns into the instrument. When an intense light pulse with the proper optical frequency is launched into the fibre, it interacts through stimulated Brillouin scattering (SBS) with the CW reflected wave, this latter being amplified while crossing the pulse. The amplification rate at any location depends on local features of the fibre, such as temperature and strain, but also, as explained below, on the relative polarisations of the waves crossing at this point. The time recording of the intensity of the reflected light gives the spatial distribution of the Brillouin gain along the fibre, that is directly related to the polarisation variations experienced by light during its propagation.

The differential Brillouin gain is given by the relation

$$d\vec{E}_s = \frac{1}{2} g(\nu)\left(\vec{E}_s \cdot \vec{E}_p^*\right)\vec{E}_p dz$$

where $\vec{E}_p$ and $\vec{E}_s$ are the pulse and CW fields respectively and $g(\nu)$ is the linear Brillouin gain coefficient. The product $\left(\vec{E}_s \cdot \vec{E}_p^*\right)$ indicates that the local gain is polarisation-dependent, being maximal for aligned fields and zero for crossed fields. The gain varies along the fibre as the relative polarisations of $\vec{E}_p$ and $\vec{E}_s$ are changed by birefringence, as shown in the measured gain profile in Fig. 2

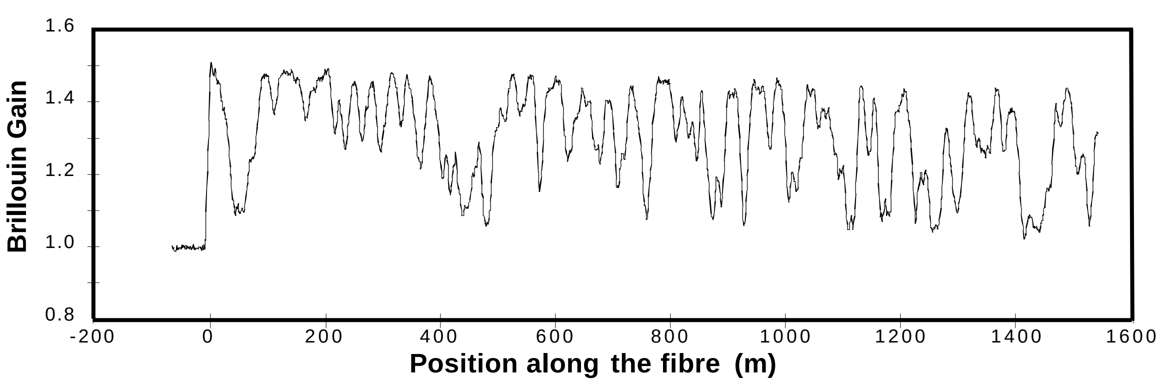

Fig. 2 *Typical Brillouin gain distribution along a standard fibre. Brillouin gain fluctuations are caused by polarisation change along the fibre.*

The information about the birefringence beat length can be extracted from such a gain profile, since the pulse and signal waves experience the same birefringence and have correlated, though not identical, polarisations. The distance between a maximum and the next minimum of the gain corresponds to a quarter of the local beat length. Fig. 3 shows the local beat length obtained from a typical gain profile, as well as the gain profile itself.

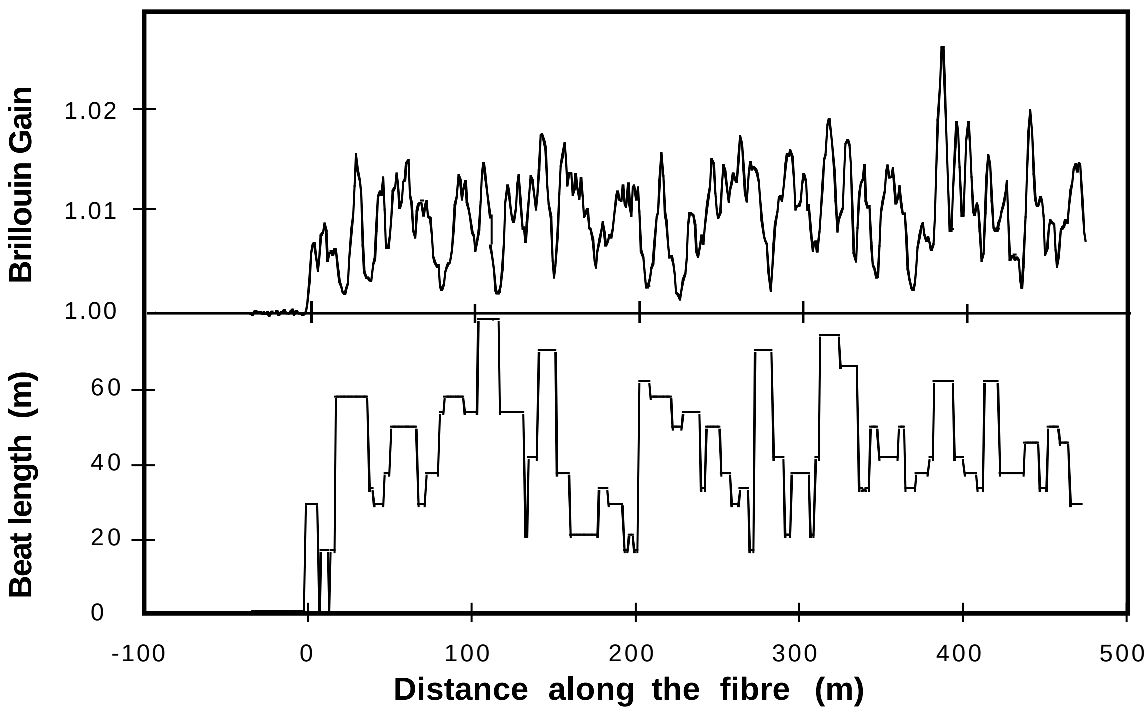

Fig. 3 *Brillouin gain distribution along a segment of fibre (top) and calculated corresponding local beat length (bottom).*

The relative polarisations of $\vec{E}_p$ and $\vec{E}_s$ can be locally changed using the polarisation controller shown in Fig. 1, so that gain can be made maximum or zero at a definite position, and complementary profiles can therefore be obtained, as shown in Fig. 4. This possibility to cancel the gain at any position indicates that the polarisations remain crossed over the whole interaction length. The spatial resolution, corresponding to the interaction length, is hence sufficient to resolve the effects of birefringence. But if the polarisation changes within an interaction length the gain is partially averaged over the polarisations, so that the gain fluctuations decrease and even vanish for complete polarisation scrambling. It has been

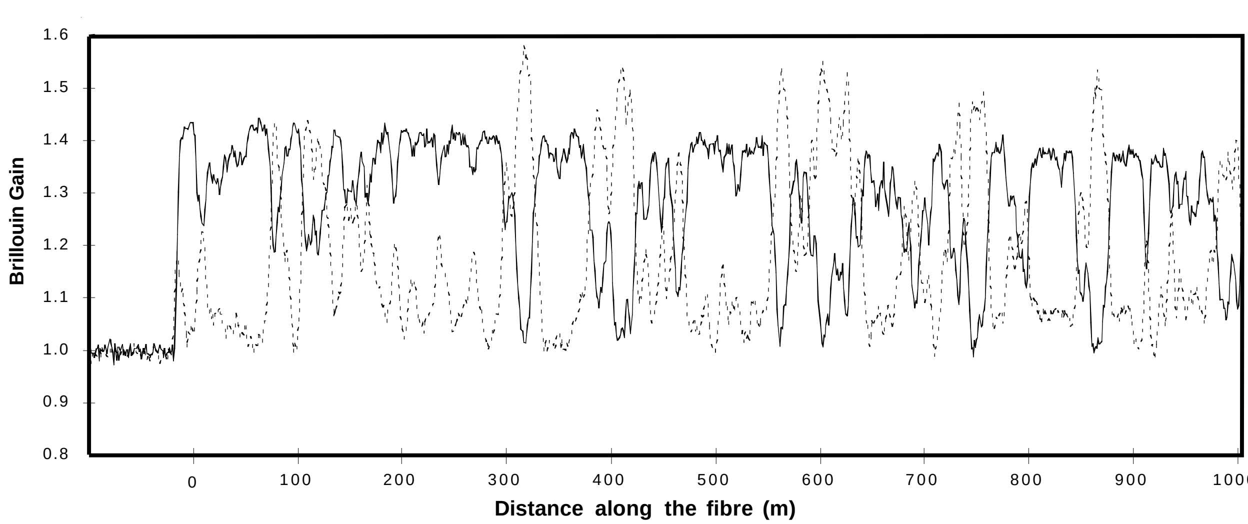

Fig. 4 *Complementary gain profiles in the case of resolved birefringence . The gain can be maximal or cancelled at any position.*

demonstrated [4] that in this case the gain globally varies over the entire fibre length between 1/3 and 2/3 of its maximal value. This unique property has been observed experimentally in many fibres using this method, and an example is shown in Fig. 5.

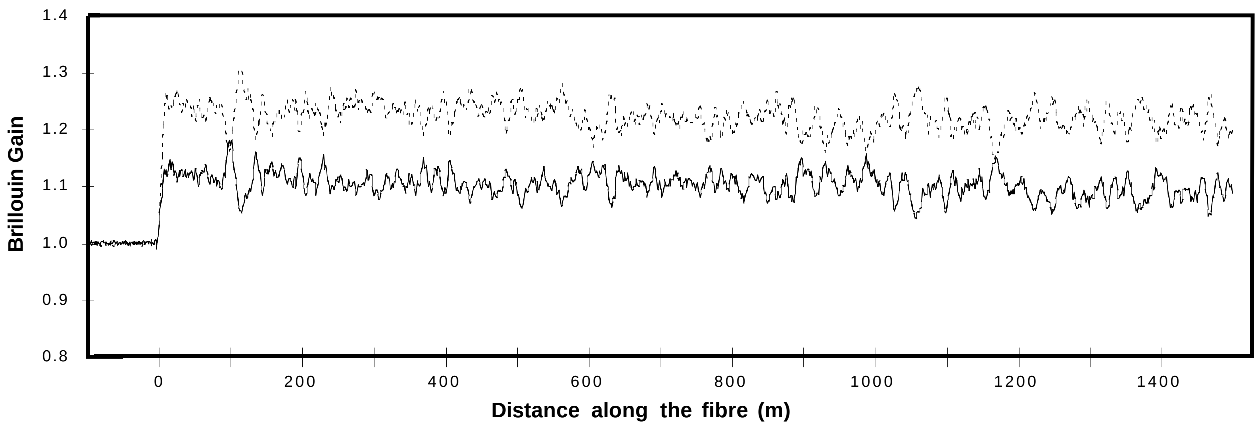

Fig. 5 *Gain profiles for unresolved birefringence., showing the two extremes cases corresponding to a gain that is 2/3 (top trace) and 1/3 (bottom trace) of its maximal value.*

In conclusion it is now well-known that local Brillouin analysis provides important informations about the strain experienced by a fibre in installed cables [3]. This paper demonstrates that such a system can also be an efficient tool to analyse the local polarisation properties of fibres. Further works using this technique are under way to extract even more information about the polarisation states and the relation with fibre PMD.

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