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Simulating the Brillouin response of arbitrary optical fibres with a finite element method

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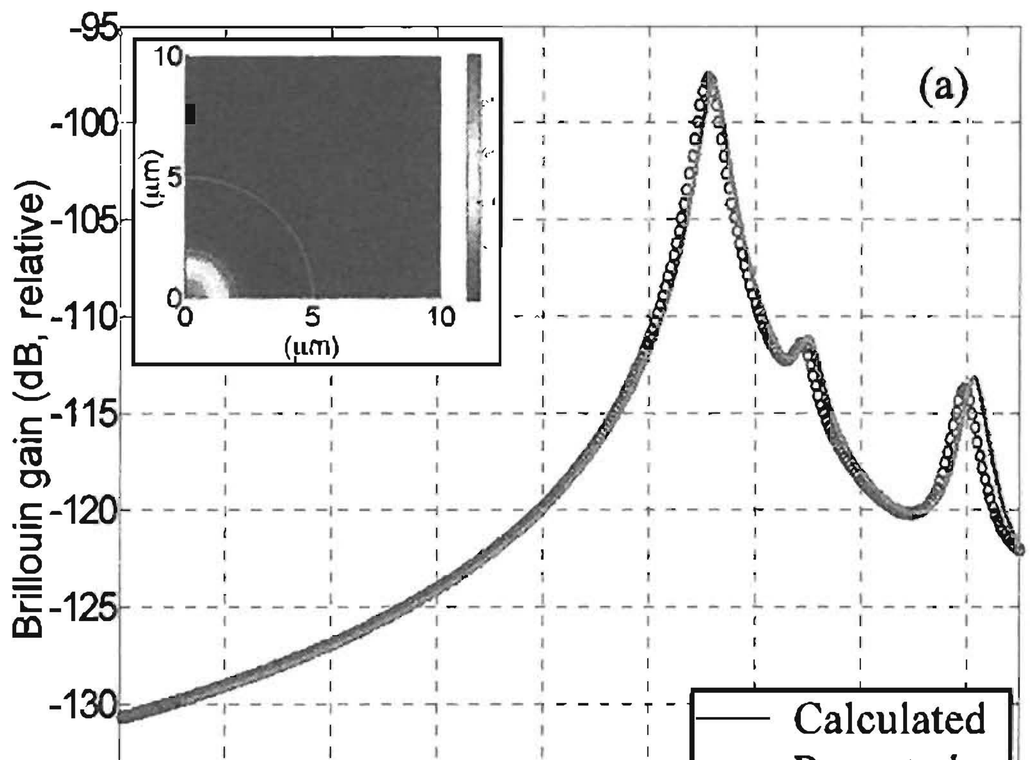
Stimulated Brillouin scattering (SBS) is an important nonlinear optical phenomenon that has been gainfully exploited in many important applications/devices such as slow light generation, Brillouin amplifiers/lasers, and distributed sensing. On the other hand, it is a highly undesirable effect in telecoms applications and in fibre-based devices like parametric amplifiers and fibre lasers. Thus, significant research efforts have been focussed on designing optical fibres with tailored acousto-optic interactions in order to enhance/mitigate their SBS characteristics, which necessitates evaluating their Brillouin gain spectrum (BGS). Various theoretical and numerical techniques for calculating BGS have been reported in recent years, though the applicability of most of these are limited to fibres with radial symmetry and/or weak acoustic guiding properties. In this paper, for the first time to the best of our knowledge, we employ a commercial finite-element method (FEM) solver to calculate the optical and acoustic modes of arbitrary longitudinally invariant fibres and thus determine their BGS. The method, a derivation of the one presented in [1], can be applied to solid fibres with arbitrary refractive index profiles, as well as to microstructured optical fibres (MOFs). Comparisons with reported simulations and with experimental results confirm the accuracy of our implementation.

Figure 1(a) shows the calculated and reported BGS of the conventional highly nonlinear fibre studied in [2], which had a core radius of 2mm and a 9% (by weight) Ge-doping in the core. Figure 1(b) shows the experimental and calculated Brillouin frequency shifts of 19 silica MOFs with different structural properties, reported in [3]. An offset of only ~20MHz (0.2% relative error) is observed for all the MOFs, which is attributed to some residual uncertainty in the amount and spatial extent of Ge-doping in the fibres. It is evident from Figure 1 that the numerical results obtained with our FEM implementation are in excellent agreement with reported and experimental results. Thus, this technique should prove to be an accurate and invaluable tool for designing novel fibres with tailored BGS for various applications.



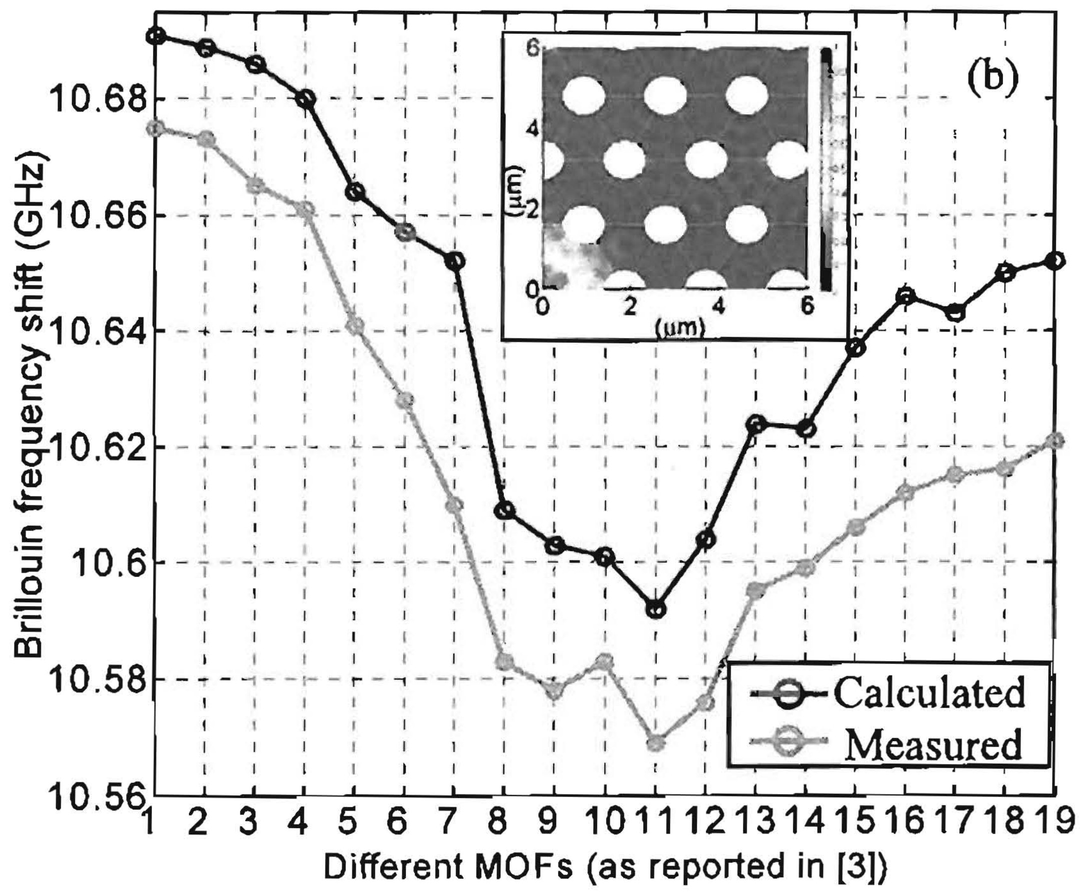


Figure 1: (a) Calculated BGS of the Ge-doped conventional fibre reported in [1]; (b) Calculated and measured Brillouin frequency shifts for all the Ge-doped silica MOFs reported in [3]. Insets show the axial displacement vectors of the fundamental longitudinal mode responsible for the main BGS peak.

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