The work presented in this thesis focuses on improving the fabrication of Fibre Bragg Gratings (FBGs) and Long Period Gratings (LPGs) in microstructure polymer optical fibres (mPOF). It also focuses on exploring new options for biomedical and acoustic sensing with the purpose of expanding the range of applications and pushing the limits. The first part of the work focuses on the fabrication of FBGs in polymer optical fibres. FBGs are a periodic perturbation of the refractive index of the optical fibre core which act as a wavelength specific reflector. The fibres used are made of Polymethyl methacrylate (PMMA) polymer, they are microstructured with a hexagonal 3-ring air-hole structure. FBG is inscribed through a Phase Mask technique where a Phase Mask is a piece of glass with a periodically corrugated surface on the nanometric scale.

When the laser light passes through it, it creates diffraction orders which will interfere with each other and together form a periodic pattern. PMMA is an intrinsically photosensitive material, which changes its refractive index upon radiation at UV wavelengths. The PMMA fibre is positioned just below the phase mask so its core refractive index is periodically altered creating a Bragg grating with peak reflection wavelengths at 650 nm or 850 nm, depending on the phase mask. As part of this work the FBG inscription system was optimised. The optimisation routine is presented and after the optimisation inscription time is reduced to just a few minutes, a considerable improvement with respect to previous inscriptions. The influence of the laser intensity on the inscription of the gratings is also demonstrated. For step index fibres the inscription is a straightforward process. For microstructured PCFs however, the holey cladding region is making it difficult for inscription light to reach the core. The hexagonal holey structure in the cladding is shown to have certain angles, where the strong grating is formed in a short time. At the unwanted angles, grating was not formed at all, or being of a very poor quality, proving the importance of fibre orientation for the inscription. As polymers are viscoelastic materials, they have properties of both viscous and elastic materials. Therefore, the investigation of long-term strain behaviour of a free-standing, unembedded polymer optical FBG (POFBG) sensor is presented. It shows that after straining polymer fibre sensor at certain strain level, the relaxation of the fibre happens in two phases, defining two wavelength ranges. The two ranges are called fast relaxation range ($\Delta \lambda_{\text{fast}}$) and slow relaxation range ($\Delta \lambda_{\text{slow}}$). $\Delta \lambda_{\text{fast}}$ is the part with higher strains and in this range fibre behaves generally elastically – it responds instantaneously to the changes in the applied strain. The $\Delta \lambda_{\text{slow}}$ is the wavelength range at lower strain levels, near the complete relaxation of the fibre, and in it the fibre is behaving generally viscously. Fibre sensor operating in the slow range cannot relax fast enough and experiences a time lag. The amount that these two ranges take of the total strain range depends on four factors: strain amount, strain duration, relaxation duration, and the number of cycles that sensor was strained and relaxed. Their dependency is reciprocal - as one increases the other one decreases: the $\Delta \lambda_{\text{slow}}$ increases with strain amount, strain duration, increasing number of cycles, and it decreases with relaxation duration. For strains up to 0.9%, fast relaxing $\Delta \lambda_{\text{fast}}$ range takes no less than 65% of the total strain range. Increase in $\Delta \lambda_{\text{slow}}$ due to cyclic straining and relaxing seems to reach an equilibrium value, suggesting that $\Delta \lambda_{\text{slow}}$ would never cover the whole strain range. When increasing the strain to 4.9%, the relative amount of $\Delta \lambda_{\text{slow}}$ grows with respect to $\Delta \lambda_{\text{fast}}$, but so does the absolute amount of $\Delta \lambda_{\text{fast}}$. With the proper prestrain covering $\Delta \lambda_{\text{slow}}$, the free standing FBG fibre sensor could operate in “real-time” entirely in $\Delta \lambda_{\text{fast}}$. It would have the highest sensing range around 3%. In the last part of the FBG section, a simple fibre FBG microphone is investigated, and the influence of a membrane amplifier on sound detection is also investigated. In the last part of the thesis the LPG inscription system is shown. In this system a high power CO$_2$ laser is used for the inscription. An LPG is also a periodic perturbation of the guided core mode in fibre, but unlike FBG which reflects the core mode, the LPG couples the core mode to a cladding mode outside the core. We have shown that the LPG grating can be formed through two mechanisms in polymer fibres using a CO$_2$ laser. One is etching and the other one is perturbation of the microstructured region. After inscription of LPGs, the concept of a biocompatible distributed medical endoscope is presented, where an all-plastic LPG based device is produced. A transducer pod is made which translates the outside pressure into strain on the fibre. The transducer consisted of a 3D printed skeleton through which the fibre is pulled. A latex material is then wrapped around it and all the holes were sealed in order to prevent the air from leaking out. The pod transducer was tested for forces acting on its arms, and subsequently put into a pressure chamber. It showed good initial results for pressures up to 150 mBars, proving itself suitable as a potential biocompatible endoscope.