Abstract
Interferometric distributed fiber optic sensing

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This thesis studies single-arm frequency-shifted interferometry (SA-FSI), a simple, compact, practical and versatile fiber optic sensing technique which has many advantages over conventional techniques. We further developed the theory of SA-FSI, and successfully demonstrate that SA-FSI can achieve long distance and high sensitivity sensing multiplexing.

Two configurations of SA-FSI have been introduced in this thesis work. In one configuration, 5 weak reflectors were put in series along two fiber links. The frequency of the driving RF signal was swept from 2.5 to 3.5 GHz at steps of 1 MHz, which leads to a spatial resolution of 0.1 m and a measurement range of 50 m. In the other configuration, we located four weak reflectors in series along a single fiber link. By sweeping the amplitude modulator driving frequency in the range between 2.7 and 3.2 GHz at steps of 41.7 KHz, a spatial resolution of 0.2 m and a measurement range of about 1 km have been demonstrated.

In this thesis work, we also build a model of the working principle of a distributed vibration sensing system developed by QPS Photronics Inc., and explore its sensing features. Three different types of reflective terminations (a QPS VibroFibre sensor, a flat end fiber, and a loop mirror) have been used in our experiments. Note that, in our experiments, the whole fiber link is essentially a “vibration sensor”, while the vibration sensor only serves as a reflector. Both fundamental frequency component $f$ and higher order harmonics (e.g. $2f$, $3f$) are observed in experiments for these three reflective terminations, which is consistent with our simulation results. We also find that amplitudes of peaks in the fast Fourier Transform (FFT) spectrum vary with time. We believe that this phenomena is mainly because environmental noise (including temperature drift in the lab, noise from ventilation, etc.) changes the polarization state of output
light from the source. This leads to the time dependence of amplitudes of peaks in the FFT spectrum, according to our model of the working principle of QPS vibration sensing system.