CHAPTER 5

CONCLUSIONS

This thesis summarized the development of three projects. The first project concerned the building and the analysis of a photorefractive oscillator. We named it an autotuning filter for its ability to automatically tune in to the strongest principal component of its spatio-temporal input space. This filter was the object of Chapter 2. The following chapter described the insertion of that optical circuit in a sophisticated RF-photonics system, which implemented principal component extraction on mixtures of two microwave signals received by a 10 GHz quasi-optical lens antenna array. Finally, Chapter 4 presented the first development stages of an optical amplifier adapted to photorefractive information processing. All three projects achieved progress toward engineering photorefractive circuits for commercial applications.

The autotuning filter's ancestors are circuits such as the feature extractor and the frequency demultiplexer. Their experimental implementations occupied about half a standard optical table (about 2 m^2) and required hundreds of milliwatts to operate. The signals processed by those circuits were within audio frequency range. The free space optics version of the autotuning filter, described in Chapter 2, processes signals with up to 3 GHz of bandwidth. The circuit fits on a quartz plate that is 3 cm in diameter and requires only 3 mW of optical power to operate. The earlier, fiber versions of the autotuning filter required about 10 mW of optical power and could process signals with bandwidths of hundreds of MHz.

Their signal separation performance was not as good as the performance of the free space optics version of the filter but the results were very repeatable. This is not the case with the free space optics version whose performance varies greatly with the alignment of the input pump beams to the oscillator. A non-optimized alignment yields a slope at the origin of 8 dB/dB, which is as good as the fiberized versions of the filter. An optimized alignment yields a quasi bistable device for input signals with powers within 10% of each other. Future work on this device should include a way to make the alignment of the input beams repeatable so that the device's performance may also be uniform from one use to the next. One solution would be to fiberize the input with single mode fibers whose alignment can be optimized once and then fixed in place.

Chapter 3 demonstrated that the use of dynamic holographic optics in microwave systems could be implemented with reasonable robustness, power consumption and size, to be convenient in practical environments. The prototype system we presented performed principal component extraction on an ensemble of signals incident on a microwave antenna array. At the end of Chapter 3 we discussed widening the processing bandwidth of our system as well as increasing the number of signals it could handle. Another direction for future work lies in implementing a more powerful method for blind source separation (BSS.) Principal component analysis (PCA) separates signals by forming a set of uncorrelated spatio-temporal signals. The characterization section of Chapter 3 showed how the PCA method fails to recognize the original source signals when the received mixtures are not spatially orthogonal. There is a BSS method called independent component analysis (ICA) that does not require spatially orthogonal mixtures. ICA yields the original source signals if the temporal behaviors of the source signals are not correlated to any degree and that the received mixtures are linear combination of these signals. ICA may be implemented with optics and electronics in two stages. The first stage performs PCA on the received mixtures. The second stage consists of a winner-takes-all opto-electronic loop that extracts one of the independent components from the principal components at its input. A prototype of such a system is currently being developed in our laboratories.

Finally, Chapter 4 presented the making of an optical semiconductor amplifier for red wavelengths. To render this device practical, the mounted chip must be incorporated in a unit that facilitates the handling and the coupling of light into and out of the amplifier. This convenient single mode amplifier unit could be inserted in a single mode ring pumped by a multi-mode beam. It was explained in Chapter 4 how that oscillator would transform a multi-mode beam carrying a temporal signal to a single mode beam carrying essentially the same information. Last and most difficult would be the realization of a fully spatially multi-mode amplifier.

In conclusion, this thesis described the miniaturization of a photorefractive oscillator capable of extracting the strongest principal component of its input signal space. The analysis and simulation of the circuit provided insight into the circuit's dynamics. This autotuning filter physically performs a task that is otherwise computationally intensive for such high bandwidth signals. Chapter 3 showed that the insertion of this photorefractive circuit in a microwave processor was reasonably practical and robust to transportation. The work on optical amplifiers adapted to our way of handling information opened the gate for designing more complex and smarter photorefractive circuits.