REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: 29-02-2012

2. REPORT TYPE: Final Performance

3. DATES COVERED *(From - To)*: 01-03-2009 to 30-11-2011

4. TITLE AND SUBTITLE
QUASI-PHASEMATCHED NONLINEAR OPTICS: MATERIALS AND DEVICES

5a. CONTRACT NUMBER: NA

5b. GRANT NUMBER: FA9550-09-1-0233

5c. PROGRAM ELEMENT NUMBER: 61102F

5d. PROJECT NUMBER: 09NE206

5e. TASK NUMBER

5f. WORK UNIT NUMBER

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10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-OSR-VA-TR-2012-1092

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution A: Approved for Public Release

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The objective of this research is to study and improve the quality and performance of important nonlinear optical materials pioneered by the principal investigator, and to study new or improved device concepts made possible by these materials.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			19b. TELEPHONE NUMBER *(Include area code)*

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Final Report
QUASI-PHASEMATCHED NONLINEAR OPTICS: MATERIALS AND DEVICES
FA9550-09-1-0233
Martin Fejer

Initial research in the area of supercontinuum (SC) was motivated by the SC generation in bulk periodically poled Lithium Niobate (PPLN) carried out by Hänsch et al. In this earlier work, there was no model for the physics underlying $\chi^{(2)}$ SC generation, so the work was purely empirical, but still resulted in octave-class SC and envelop locking with both 1.08-µm Yb:fiber and 1.5-µm Er:fiber pumps. Under this AF-supported program, a numerical simulation tool for octave-spanning $\chi^{(2)}$ processes was developed, that elucidated the mechanisms underlying the empirical results, and made predictions in quantitative agreement with the experimental observations. This analysis showed that a complex combination of cascaded $\chi^{(2)}$ processes, self-phase modulation, cross- phase modulation, and Raman effects all contribute, and that the group velocity dispersion in the vicinity of the pump wavelength and are important factors influencing the breadth and structure of the generated SC.

Based on these results, a heuristic picture for designing QPM gratings with $K_g(z)$ trajectories that accomplish specific goals, e.g soliton self-frequency shift, SC generation, etc. emerged, and could then be optimized with the numerical simulation tool. Generation of broader and flatter SC would be a goal in future research.

As a first demonstration of the utility of bulk periodically oriented gallium arsenide (OPGaAs) materials for broadband ultrafast mid-IR devices, a soliton self-frequency shift in a fluoride fiber to generate a 50-fs-long 2.5-µm pulses from a 150-fs-long 1.95–µm pump pulses from a Tm:fiber laser was used, and then those difference-frequency mixed pulses were used in an OPGaAs crystal to generate frequency combs in the 7-12 µm region. The wavelength of these spectra was tuned through the use of an OP-GaAs crystal with a fan-shaped QPM grating, translation of which through the pump beams controlled the QPM grating k-vector encountered by the beams. The results were again in quantitative agreement with the predictions based on a simulation tool.