Study of limiting factors and methods of optical phase conjugation by stimulated Brillouin scattering

by

Igor Yu. Anikeev

Thesis submitted for the degree of

Doctor of Philosophy

in

The University of Adelaide

Department of Physics and Mathematical Physics

July, 2000

Contents

Abstract

A study of phase conjugation by stimulated Brillouin scattering (SBS) is presented with emphasis on the influence of limiting factors, such as aperture and polarization losses, spatial coherence and saturation of the incident wave on the quality of phase conjugation, as well as the application of SBS to two practically interesting configurations, namely: the loop phase-conjugated mirror and intracavity-SBS-cell phase-conjugated oscillator.

The thesis can be divided into two parts. The first one covers the period from 1982 to 1995 when I was with P. N. Lebedev Physical Institute of Russian Academy of Science. Chapters Two, Three, and Four describe the research done in that time. These chapters are not just overviews of the subject literature found in most of theses, but also represent early original works by me and my colleagues. Credits go to Prof. N. G. Basov, Mr. D. A. Glazkov, Mr. A. A. Gordeev, Mr. A. B. Mironov, Mr. S. I. Mikhailov, and Dr. I. G. Zubarev for being my co-authors and collaborators. The second part of the thesis covers the period from 1997 to 2000 when I was a Ph.D. student at The University of Adelaide. Chapters Five and Six present the results obtained for these last three years. Credits go to Prof. J. Munch for being my Ph.D. supervisor.

The thesis consists of seven chapters. **Chapter One** presents the research objectives of the thesis, puts the work in context with the literature and highlights other results of the author's research done in the field of phase conjugation but not included in this thesis.

Chapter Two is devoted to a theoretical study of spatial coherence and pump saturation in stimulated scattering. The model developed leads to a significant simplification of the dynamical equations, which can then be analyzed for arbitrary relations between the characteristic lifetimes of the respective oscillations and the reciprocal width of the pump spectrum. The space-time structure of the scattered Stokes radiation is computed for different numbers of the spectral components of the pump. A comparative study of the collinear and counter propagation interactions of

a Stokes field with pump radiation is carried out. A theoretical investigation of stimulated scattering of spatially inhomogeneous radiation under saturation condition is also made in Chapter Two. A system of kinetic equations describing the interaction between the pump radiation and Stokes waves, correlated and uncorrelated with the exciting field, is derived and solved. A quantitative criterion is derived for the quality of phase conjugation for two practical cases of the Stokes radiation generation.

Chapter Three contains investigations of the influence of polarization and aperture losses on the performance of phase-conjugating mirror systems. The losses are described by means of the overlap integral. They lead to the appearance of unremovable noise in the background of the reproduced radiation. Different possible situations are analyzed both theoretically and experimentally.

Chapter Four is concerned with the generation of Stokes waves in the loop application of a phase conjugate mirror. Angular selectivity, the reflectivity threshold, and the duration of the linear stage of the development of lasing are investigated experimentally. Near-field and far-field spatial distributions are measured for different lengths of the loop. A method of phase conjugation with a high energy efficiency is implemented.

Chapter Five investigates a phase conjugate oscillator with an intra-cavity stimulated-Brillouin-scattering cell. The oscillator resonator design is developed for a stable single-pulse emission. Dynamics of the Q-switch pulse development is analyzed. An interferometric technique is used for the measurement of coherence length of the output pulse at different levels of the pump energy. Coherence length limits are estimated and compared with the experimental results.

In **Chapter Six**, a method of improvement of the output performance of a phase conjugate oscillator is described. An additional extra-cavity stimulated-Brillouin-scattering cell creates a master oscillator + power amplifier configuration from a single laser rod. This design allows improvement of temporal characteristics of the laser emission as well as an increase in the peak output power. The beam quality is measured in the course of the experiment by using an autocalibrating technique.

Finally, conclusions drawn from the work performed in this thesis are presented in **Chapter Seven**.

In the **Appendices**, I include various derivations plus full list of my publications and one reprint for every chapter (chapters Two to Six).