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Temporal and Spatial Instabilities and Nonlinear Beam-Steering of Light in Periodic Media

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Abstract

The presentation will treat the propagation of light in nonlinear periodic structures using an approach based on the normal modes of linear periodic structures – the Photonic Bloch waves (PBW's)[1,2]. These waves exhibit rich and complex behaviour in the presence of optical nonlinearities, in part because they consist of a group of backward and forward waves superimposed and sharing the same group velocity or evanescent decay rate[3,4]. The nonlinear dispersion relation of these waves is straightforward to obtain and can be solved analytically[4]. Its simplicity makes it easy to assess the susceptibility of nonlinear PBW's to modulational instability (MI). In the presence of MI, signals injected at side-bands of the pump wave experience gain or loss via degenerate four-wave mixing. In the temporal domain this means that spurious signals can grow from noise at frequencies ranging from MHz to THz, depending on the strength of the linear grating[5]. The result is oscillation and instability; a spin-off of the MI analysis is that regions of stability and bistability are easily identified. Perhaps even more intriguing is the behaviour in the spatial domain, where temporal frequency translates to spatial frequency or angle; the MI sidebands in this case grow and propagate in directions different from that of the pump wave. The pump wave itself exhibits bistability in certain regimes, leading to nonlinear beam steering where the propagation direction depends on both the pump power level and the route by which it is reached. The general behaviour of nonlinear PBW's in two-dimensional periodic media involves both temporal and spatial effects, giving rise to spatial and temporal beam fan-out and instabilities. Once their physics has been fully understood, exotic applications of these effects – in addition to established work on gap solitons[3] – are certain to emerge. At present much still remains to be done on understanding the complex behaviour of nonlinear PBW's; the talk will feature recent results from work-in-progress.

1. P.St.J. Russell, J.Mod.Opt. **38** (1599-1619) 1991.

2. P.St.J. Russell, Phys.Rev. A **33** (3232-3242) 1986.

3. See: C.M. de Sterke and J.E. Sipe, Phys.Rev.Lett. **63**(811) 1989.

4. P.St.J. Russell, in Technical Digest of *Topical Meeting on Nonlinear Guided-Wave Phenomena*, Cambridge, U.K., September 1991;

5. P.St.J. Russell and J.-L. Archambault, *Modulational Instability Gain Spectrum of Nonlinear Photonic Bloch Waves in Periodic Media* submitted to IQEC'92, Vienna, June 1992.