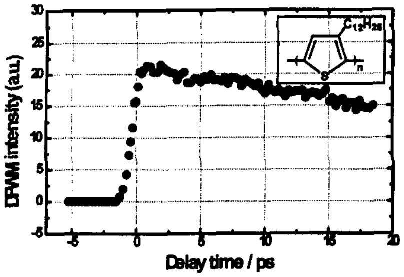

QWE4 Fig. 1 Temporal profile of optical pumping effect on DFWM intensity as a function of a delay time between pump pulse at 400 nm and two probe pulses at 800 nm.

pumping effect on DFWM intensity was independent of the polarization angle of pumping pulse at 400 nm. These results suggest that the enhancement of DFWM intensity by optical pumping might be ascribed to the gain of the electronic third-order susceptibility. Exciton states were well known to be created in one-dimensional chain backbone of a conjugated polymer by optical excitation.[5] Exciton states possess an intense transition to higher excited states in a region from near IR to IR. That might be one of the mechanisms for the optical pumping enhancement of DFWM intensity.

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QWE5

Optical bistability in reflection-mode operation of a diode laser amplifier

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A number of physical systems exhibit hysteresis and bistability, ranging from electronic devices like a Schmitt trigger, to quantum devices like the single-atom micromaser. Lasers, and laser diode amplifiers (LDA) have been demonstrated to exhibit dynamical hysteresis, and the intimate connection between this bistability and delayed bifurcations has been theoretically and experimentally elucidated. Bistability and hysteresis in LDAs is especially interesting for its potential application in developing optical switches and logic gates. For LDAs, Roy and coworkers[1] have demonstrated that the width of the hysteresis loop in the output of the amplifier, when an input signal is periodically modulated, increases with an increase in the frequency of modulation. These workers derived scaling laws for the width of the hysteresis versus frequency, for different bias conditions of the amplifier. Most previous experiments that examined hysteresis in amplifiers utilized the amplifier in a transmission mode, where the light transmitted through the amplifier was monitored. Reflection mode operation of diode laser amplifiers has not been as thoroughly investigated, though it is expected to be of relevance to some forms of logic gates, such as NAND and NOR gates.

We report results of an experiment in which the output of a single-mode diode laser is injected into a diode laser amplifier operated close to its lasing threshold. The injected light is periodically modulated at frequencies very slow compared with the relevant relaxation frequencies within the amplifier. In contrast to most experiments, we operate the amplifier in a reflection mode instead of the transmission mode. Under the influence of the periodic modulation, the amplifier output exhibits several novel types of hysteresis and associated bistable behavior. Specifically, we find that for some operating conditions, determined by the amplifier bias current and temperature, one obtains a reversal in the direction of the hysteresis, where the output of the amplifier switches from the conventional positive hysteresis, to negative hysteresis. Our measurements follow the route taken by the hysteresis as it switches directions, which indicates that an X-shaped hysteresis is the intermediate step. For positive hysteresis, the width of the hysteresis loop increases with an increase in the modulation frequency, and we find a scaling exponent that is different from those reported in the literature.[1] The negative hysteresis is a new dynamical phenomena, and theoretical work is currently underway to analyze the experimental observations.

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QWE6

Transition to an oscillator for double phase-conjugate mirror

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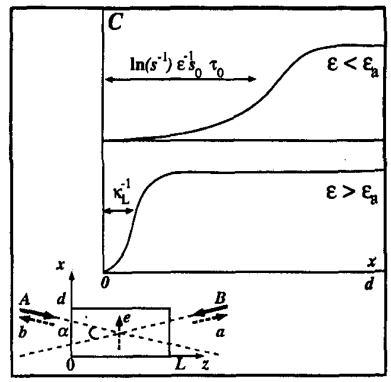
Double phase conjugate mirror (DPCM) is a unique device in which two mutually incoherent pump beams are phase conjugated[1] simultaneously, (Fig. 1, inset). Currently there is a disagreement in the field about the nature of the linear instability (oscillator or amplifier[1,2]). The controversy originates from the wide gap in complexity between the analytical problems considered and the usual experimental conditions. The more realistic, numerical studies[3] and experiments exhibit a rich spatial behavior for the DPCM. The nature of the linear instability is essential for understanding the behavior of DPCM in different regimes and hence for improving the device performance.



QWE6 Fig. 1 The profile of the nonlinear front solution for $\varepsilon < \varepsilon_a$, $\varepsilon > \varepsilon_a$. Inset: DPCM configuration.

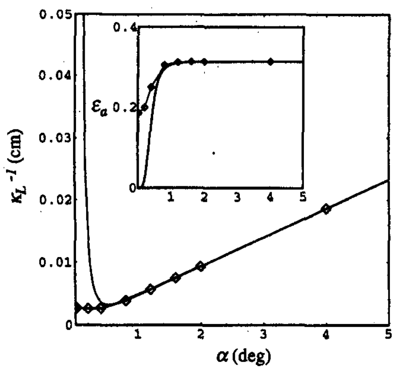
The problem is approached as one of pattern formation outside of equilibrium[4] and an "amplitude equation" is derived. This equation is an established, unified approach to systems that exhibit critical transitions. It has been successful in quantifying many of the experimental observations in these systems. Here, some of the novel quantified characteristics for DPCM are the effects of the nonlinearity on the critical dynamics (approach to saturation) and on the spatial distribution of the grating (large scales distortion of the beams and conjugation fidelity) and sensitivity to noise (seeding). The approach also clarifies the question of linear instability and predicts a new transition to an oscillatory regime.

A slow modulation C of the phase-matched, shared grating (with grating wave number k_g), as $C\exp(ik_g x)$ is considered. The "amplitude equation" governs the spatial and temporal evolution of C in the weakly nonlinear regime:

$$\tau_0\partial_t C + \tau_0 s_0 \partial_x C = \varepsilon C - \xi_0^2(1 + jc_1)\partial_x^2 C - g_0|C|^2 C \quad (1)$$

Equation (1) is derived from the Helmholtz and Kukhtarevs equations for photorefractive effect using a perturbative approach, "multi-scaling analysis,"[4] with the smallness parameter, $\varepsilon = ((\Gamma L)_c - \Gamma L)/(\Gamma L)_c$, ($\Gamma L$, gain-length product, $(\Gamma L)_c = -2$ for degenerate pump beams). The coefficients of Eq. (1) are calculated for different system parameters: α, the full angle between the two pump beams, pump intensity ratios and frequency difference; Debye length, etc.

The behavior of the convective system above the threshold is readily predicted from Eq. (1). For small ε there is exponential growth of C in the $+x$ direction away from the lower boundary (Fig. 1) as the noise is amplified while the group velocity, s_0, carries the disturbance upward, until the nonlinear term in Eq. (1) saturates the growth. The length over



QWE6 Fig. 2 κ_L^{-1} as a function of α. Inset: ε_a as a function of α (for degenerate pump beams); thick solid lines, analytical solution; diamonds, numerical solutions.

which the solution grows to saturation $\ln(s^{-1})\varepsilon^{-1}s_0\tau_0$ (with s the seed at the lower boundary) can be quite large near threshold and for small noise, leading to large scale distortions in the grating amplitude and hence the beams. As ΓL is increased further the system exhibits a transition to oscillator. Above this transition the front shown in Fig. 1 has propagated backward, since now the growth dominates the advection, to fill the region with the saturated nonlinear solution except for a "healing" length near the lower boundary, which is now independent of the noise level and only depends on the parameters of the amplitude equation (the characteristic length $\approx\xi_0$ and $\varepsilon_a \approx 0.3$). The developed grating is not sensitive to fluctuations in the seed level and is self-sustaining even in the absence of noise (a characteristic behavior of self-oscillation). The transition to this state is precisely determined by the zero propagation velocity of the front solution connecting the nonlinear state to the zero amplitude state.[5]

The propagation velocity of the front in Eq. 1 is given by a stationary phase analysis. The analysis yields the following transition parameters:

$$\varepsilon_a = s_0^2\tau_0^2/[4\xi_0^2(1 + c_1^2)] \qquad (2)$$

$$\kappa_L = -\varepsilon^{1/2}/[\xi_0(1 + c_1^2)^{1/2}], \qquad (3)$$

where the tail of the stationary front is of the form $\exp\{-j(q_L - j\kappa_L)x + (\Omega_r + j\Omega_i)t]\}$. Equation (2) identifies the transition ΓL value to be about -2, $-2\varepsilon_a \approx -2.6$. Figure 2 shows ε_a and κ_L^{-1} as functions of α for degenerate pump beams. The disagreement between the two sets (numerical, analytical) at small α originates from the growing importance of the grating wave number dependence of ΓL relative to the phase matching.

We expect careful experiments will reveal that double phase conjugation transforms from convective amplifier into an oscillator at closely spaced gain thresholds.

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QWE7

Light structures created in one spatial dimension

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A fiber ring resonator constitutes a model system of a nonlinear feedback system in which the combination of self-phase modulation, group velocity dispersion, and interference can create amazingly complex phenomena. We consider such a resonator, driven by a sequence of picosecond pulses from a modelocked laser. We report on experiments and corresponding numerical simulations that reveal a wide variety of possibilities, depending on the choice of parameters.

In the simplest case, one can have a sequence of pulses with stationary shape resembling the input pulse shape but with pulse powers varying from shot to shot in a periodic or even nonperiodic way; these are referred to as sequences that are subharmonic to the repetition rate, or chaotic. More intriguingly, the pulse shapes can be modified substantially with respect to the smooth input pulse shapes; rich substructures can evolve. There are sequences of pulses in which no pulse shape is ever repeated.

Among the cases of nonrepetitive pulse shape, one has to distinguish between conditions of normal or anomalous group velocity dispersion. For normal dispersion we obtain what we call optical turbulence: a spatiotemporal instability that can be described in terms borrowed from fluid dynamics ("spatial" here refers to the light propagation direction and encompasses just a single spatial dimension). For anomalous group velocity dispersion there is formation of subpulses that have properties of solitons, are localized at (effectively) random positions within the width of the input pulses, and move around. This case we call a (one-dimensional) soliton gas.

It goes without saying that nonlinear resonators are ubiquitous in all kinds of optical systems, including lasers. We will discuss relations to instabilities recently reported from some other systems in the light of the findings from our passive fiber ring resonator, which is simple enough to allow some detailed understanding, yet complex enough to create an amazing richness of types of behavior.

QWE8

Role of self-focusing and phase modulation in the large spectral bandwidth stimulated Rayleigh scattering

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The study of Rayleigh light scattering is interesting not only for its applications such as phase conjugation but also as a way to explore the interactions between matter and light. Recently a large spectral bandwidth stimulated scattering from CS_2 has been investigated in bulk,[1-3] liquid hollow-core fibers,[2,3] and microdrops.[4,5] However, despite all the results and explanations, one question remains: the origin of such a large spectral broadening mostly because several physical processes are involved simultaneously in the scattering. We discuss the role of self-focusing and phase modulation on the large spectral bandwidth stimulated Rayleigh-wing scattering (SRWS).

In the experiment a Nd:YAG laser is used to provide pump pulses of 25 ps at λ = 532 nm. The laser beam is usually focused by a 1-m focus lens into a 1-cm-long cell containing CS_2. The scattered light generated in both forward and backward directions is sent to a spectrograph and CCD image systems for spectral and spatial analyses. A microscope associated with the spectrograph is also employed to study local behaviors of the phenomenon.

The forward and backward large band SRWS at high excitation levels have been well described in Ref. 1. In completing that work, we now pay more attention to the start of the SRWS and its developments. At an excitation near threshold of SRWS, we can see clearly the presence of Kerr effects such as self-focusing and phase modulation. We have found also that these effects play a dramatic role in the generation of the large band SRWS.

The role of self-focusing is, in short, to induce and to localize the source of SRWS. That is strongly supported by the following results: (i) the self-focusing process starts before the generation of SRWS, and the focused beam has a diameter on the order of 6 μm at the end of the cell; (ii) forward and backward scatterings are produced in the self-focusing zone; (iii) the ratio of the thresholds of SRWS: linear polarization state over circular polarization state is measured at 2.6. However the calculation gives two values of 0.6 and 3.6, respectively, for the cases of a threshold resulting from pure scattering effects and to pure self-focusing effects; and (iv) the calculated threshold value of SRWS in our excitation condition is at least 10 GW/cm^2, whereas we obtain SRWS at an incident intensity of 0.8 GW/cm^2. Therefore, self-focusing increases local intensity allow SRWS to reach its threshold.

The role of phase modulation is shown by the spectral observation near the threshold excitation. It can be sum-