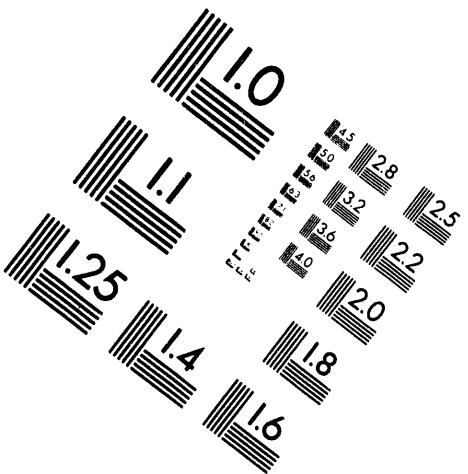




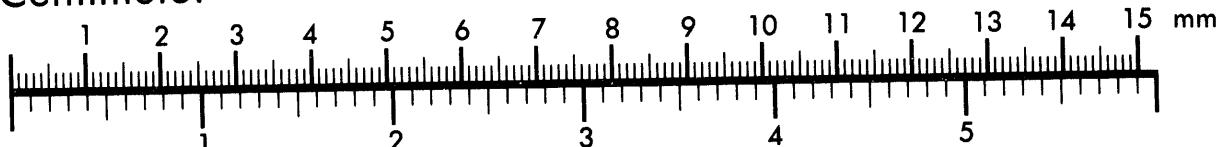
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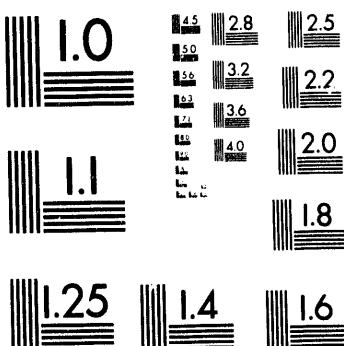
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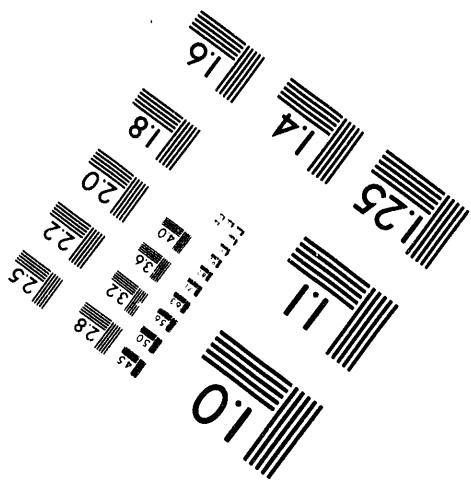
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ULTRAFAST NONLINEAR OPTICAL RESPONSE OF FANO RESONANCES IN GALLIUM ARSENIDE UNDER HIGH MAGNETIC FIELD

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Abstract

Using transient four-wave-mixing, we compare the coherent emission from the exciton resonance in GaAs at zero magnetic field with that from the Fano resonance at high field (10T). We find a surprising relation between linewidth and decay time.

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Fano interference results from the coupling between a discrete energy level and a continuum of states whose energies overlap. In the linear absorption spectrum, a Fano resonance manifests itself in an asymmetric lineshape with a minimum at the energy where the contributions of the discrete state and the continuum interfere destructively [1].

Using femtosecond spectroscopy, we study for the first time, the dynamics of the coherent emission from Fano resonances and compare it to that from an isolated Lorentzian line. We find that despite the very narrow frequency lineshape, the coupling to the continuum induces an almost instantaneous nonlinear optical response.

Experiments are carried out in bulk GaAs, where an applied magnetic field leads to the formation of discrete magneto-exciton states. The higher-order magneto-excitons energetically overlap with the 1-dimensional continua of states with k parallel to the field and Fano resonances are formed. The zero field absorption spectrum of the sample (Fig. 1a) shows that the heavy hole (hh) and light

hole (lh) exciton resonances are split due to uniaxial strain [2]. The typical Fano lineshape is clearly observed both for hh and lh magneto-excitons at $B=10\text{T}$. The temporal behavior of the polarization stimulated from Fano and Lorentzian resonances is studied by transient four-wave-mixing (FWM) experiments with co-circularly polarized 100-fs pulses.

The power spectra of the FWM signals are shown in Fig.2, under excitation conditions summarized in Fig.1, and for an excitation density $N \approx 2 \cdot 10^{16} \text{ cm}^{-3}$. Fig. 2a exhibits two peaks close to the hh and the lh exciton resonances seen in Fig.1. The FWM spectrum of Fig. 2c, obtained for excitation in the 3D continuum at zero field, simply reflects the laser spectrum. The spectrum of the FWM emission from the Fano resonance, Fig.2b, appears as an asymmetric line much narrower than that from the excitons. The position of this line is between the minimum and maximum of the absorption spectrum of Fig.1b. From this narrow FWM power spectrum, one would expect a much slower decay of the Fano resonance polarization as compared to both the exciton and zero-field continuum polarization. Surprisingly, as shown in Fig. 3b, the coherent emission from the Fano resonance decays so fast that it cannot be resolved with 100-fs pulses (autocorrelation shown in Fig.3d) and is much faster than that of the exciton, Fig.3a. Time-resolving the emission by cross-correlation [3] confirms that the Fano resonance emission is quasi-instantaneous. The emission decay in the continuum (not shown) is as fast as expected. This demonstrates that the usual relation between linewidth and decay time does not hold for Fano resonances. We attribute the narrowing of the Fano FWM spectrum and the fast temporal decay to quantum interferences between the discrete and the continuum states. The intrinsic character of this behavior was demonstrated by lowering the excitation density by one order of magnitude. Under these conditions, Fig. 3c, the temporal profile does not change significantly.

In summary, FWM experiments show that the quantum interference between a discrete state and a continuum, which gives rise to Fano resonances, leads to both a fast decay of the Fano resonance polarization and a narrowing of the FWM power spectrum, so that the usual relation between linewidth and decay time does not hold.

This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Division of Materials Sciences of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

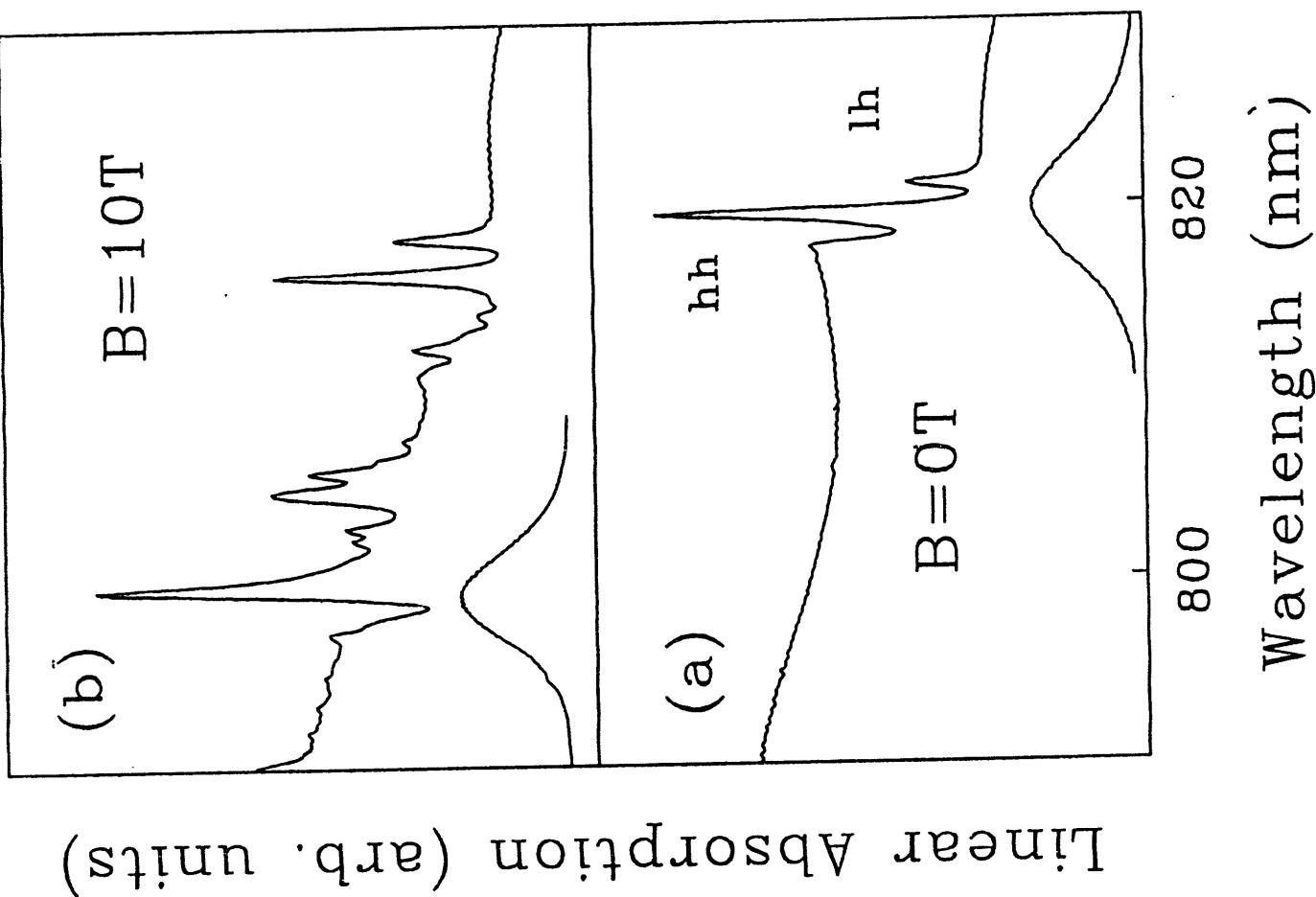
- [1] U. Fano, *Phys. Rev.* 124, 1866 (1961)
- [2] Fred H. Pollak and Manuel Cardona, *Phys. Rev.* 172, 816 (1968)
- [3] M.-A. Mycek, S. Weiss, J.-Y. Bigot, S. Schmitt-Rink, D.S. Chemla, W. Schaefer, *Appl. Phys. Lett.* 60, 2666 (1992)

FIGURE CAPTIONS

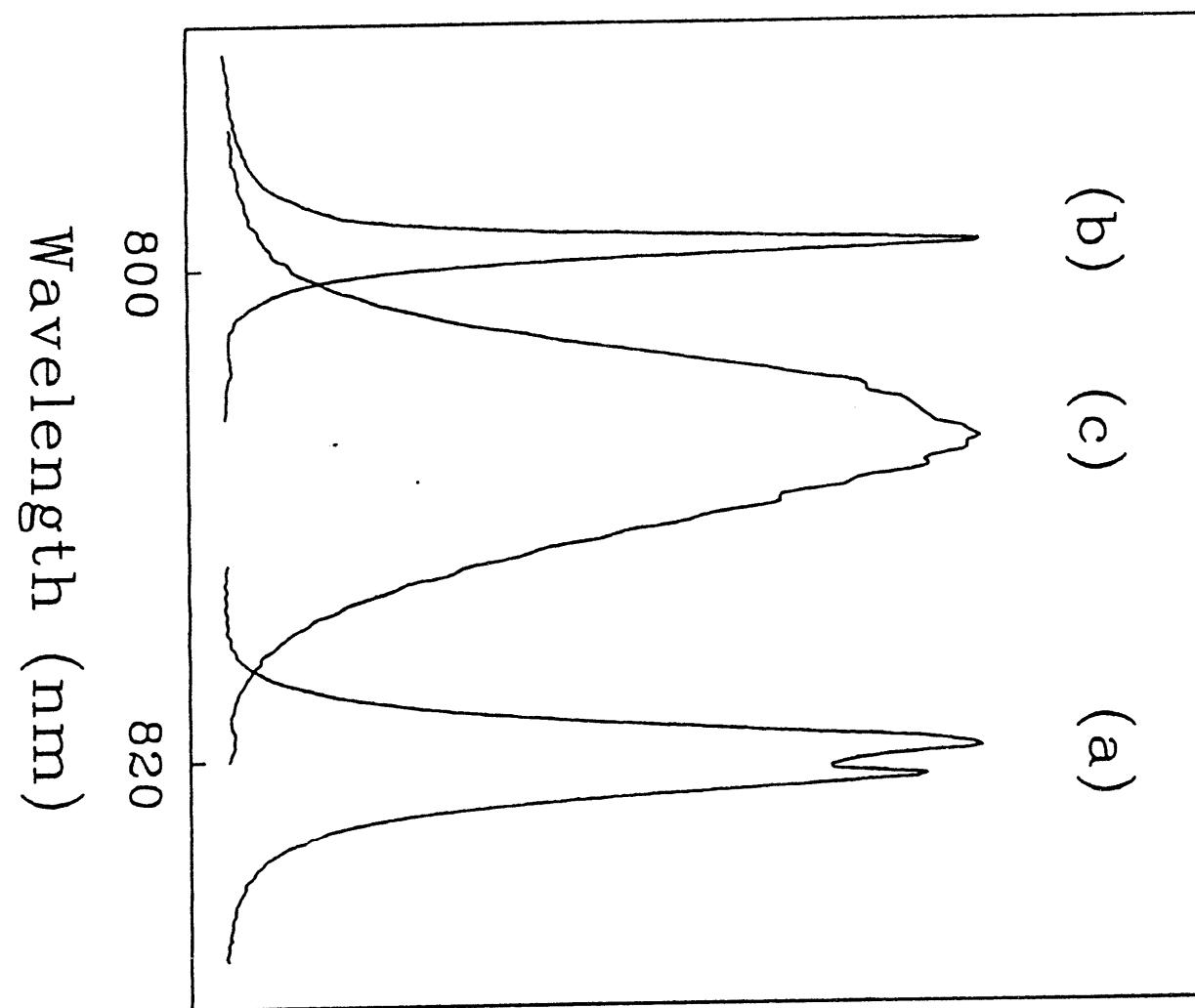
Fig.1 Low-temperature linear absorption spectrum of bulk GaAs at zero field (a) and at a magnetic field of 10 Tesla (b) measured with circularly polarized light. In order to indicate the excitation conditions in the four-wave-mixing experiments, the spectra of the exciting laser pulses are also shown.

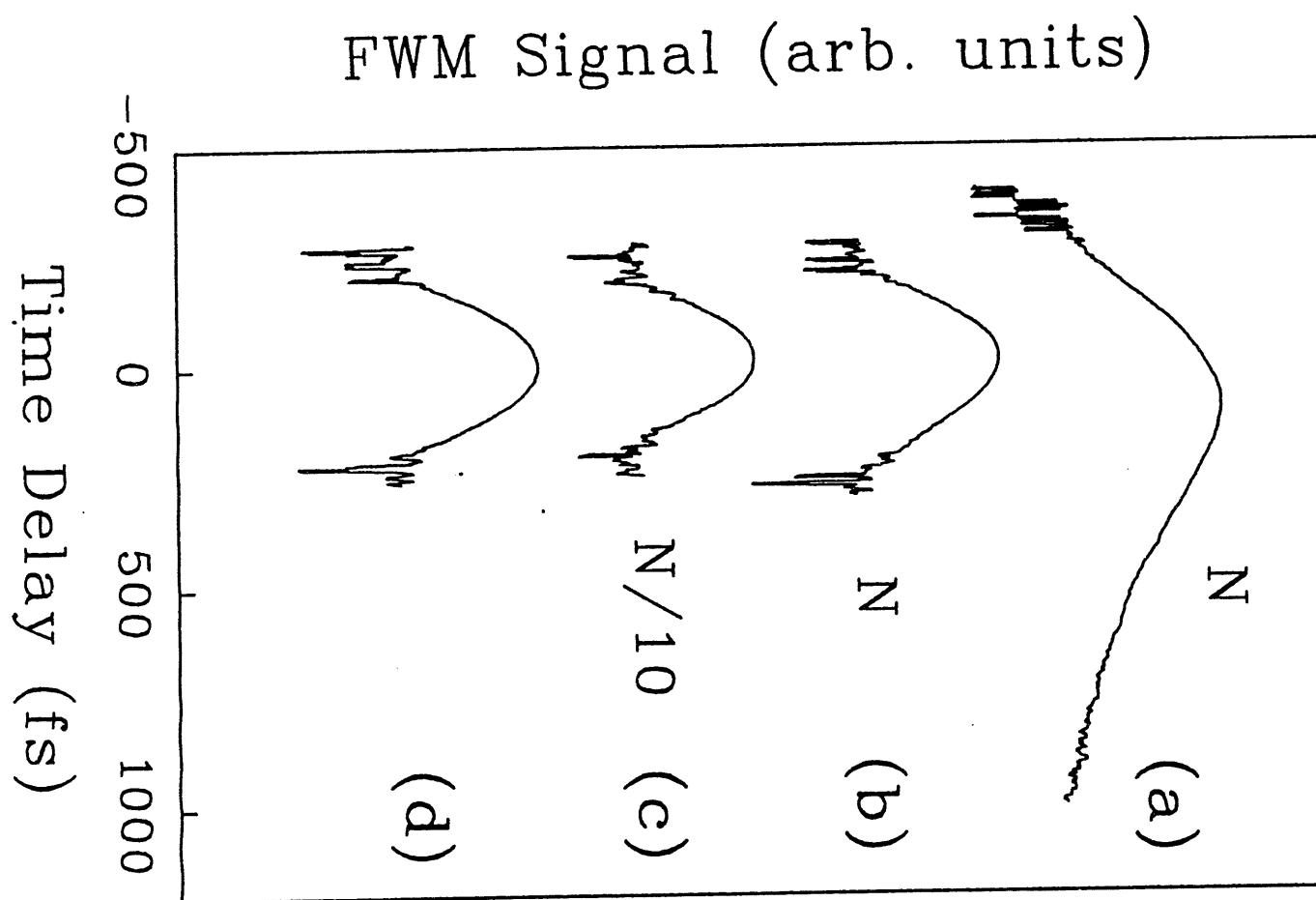
Fig.2 Power spectrum of the four-wave-mixing signal for different excitation conditions: (a) excitation of the exciton resonances at zero magnetic field, (b) excitation of the hh Fano resonance at 10 Tesla, (c) excitation in the 3-dimensional continuum at zero magnetic field. The spectra are taken at an excitation density $N \approx 2 \cdot 10^{16} \text{ cm}^{-3}$. The temperature is 1.6 K.

Fig.3 Time-integrated intensity of the four-wave-mixing signal versus the time delay between the excitation pulses: (a) excitation resonant to the exciton transitions at zero magnetic field and at an excitation density $N \approx 2 \cdot 10^{16} \text{ cm}^{-3}$, (b) excitation of the hh Fano resonance at 10 Tesla, excitation density $N \approx 2 \cdot 10^{16} \text{ cm}^{-3}$, (c) excitation of the hh Fano resonance at 10 Tesla, excitation density $N/10 \approx 2 \cdot 10^{15} \text{ cm}^{-3}$, (d) autocorrelation of a typical laser pulse. The temperature is 1.6 K in all experiments.



FWM Power Spectrum (arb. units)





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333

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