Measured Signal and Group Velocity for an Optical Pulse Propagating through a GaAs Cavity

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Abstract: We present measurements of the signal and group velocities for chirped optical pulses propagating through a GaAs cavity. Even when measured group velocity becomes negative the measured signal velocity is always less than *c*/n.

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A rough definition of the signal velocity is the velocity at which the minimum detectable signal propagates[1]. Based on this definition, if one were asked to measure the signal velocity a first reasonable reaction might be to say that the signal velocity is not well defined and it's difficult to detect single photons. Yet, the speed at which the signal travels is by all accounts an important quantity. As a starting point we define an "operational signal velocity." Since noise sources and drift are just a few potential problems to minimize, every apparatus will have a minimum threshold level at the detector in which a signal can be distinguished from the noise at a specified error probability. For our experimental setup, the amplitude of the pulse propagating through free space provided a 71 mV detector level and we chose a threshold level of 2 mV. The rms noise level was 0.2 mV for a signal to noise ratio of 10. Already we have imposed a somewhat arbitrary condition on the signal velocity by defining a 2 mV threshold level at the detector. However, in a real communication system, a threshold level is usually imposed on the system. In spite of the limitations of an operational signal velocity, several observations can be made regarding the group velocity and the signal velocity for pulses traversing a cavity. The GaAs cavity consists of a GaAs substrate, 450 μm thick with the faces uncoated. The generated optical pulse is slightly under 1 ns FWHM and it is chirped. The group velocity for a given wavelength was determined by finding the peak position of the pulse that propagated through free space and the peak position of the pulse transmitted through the GaAs cavity as before. The time difference between the peak positions is the group delay time. A similar procedure is used to determine the transit time of the signal. For the transmitted pulse and the free space pulse, the time at which the leading edge of the pulse rose to the 2 mV level was recorded. Their difference is the delay time of the signal. The actual transit time of the signal is the measured delay time plus D/*c* where D is the length of the cavity. We emphasize that the transmitted pulse is not rescaled in amplitude when determining the signal transit times. We plot the experimental transit times instead of the group and signal velocities. The measured transit times associated with the group(triangles) and signal(squares) velocities are plotted in Fig. 1 along with the theoretical and measured(circles) transmittance of the GaAs cavity. Also plotted is the phase time(thin solid line) for Fourier limited pulses. The signal and group transit times are equal when the transmittance of the cavity is unity. For all other values of transmittance, the signal transit time is longer than the group transit time. Note the exception to this in Fig. 1 for chirped pulses at wavelengths just shorter than the cavity resonance where the signal velocity slightly exceeds the group velocity. Also, the transit time of the signal is longest when the transmittance reaches a minimum. Finally we have reported, to the best of our knowledge, the first measurements of the group velocity and operational signal velocity for optical pulses transmitted through a cavity. We do not claim to have measured the signal velocity of the minimum detectable signal. In spite of this limitation we believe that much insight has been gained into the relationship of the group and operational signal velocities for pulses propagating through a cavity.

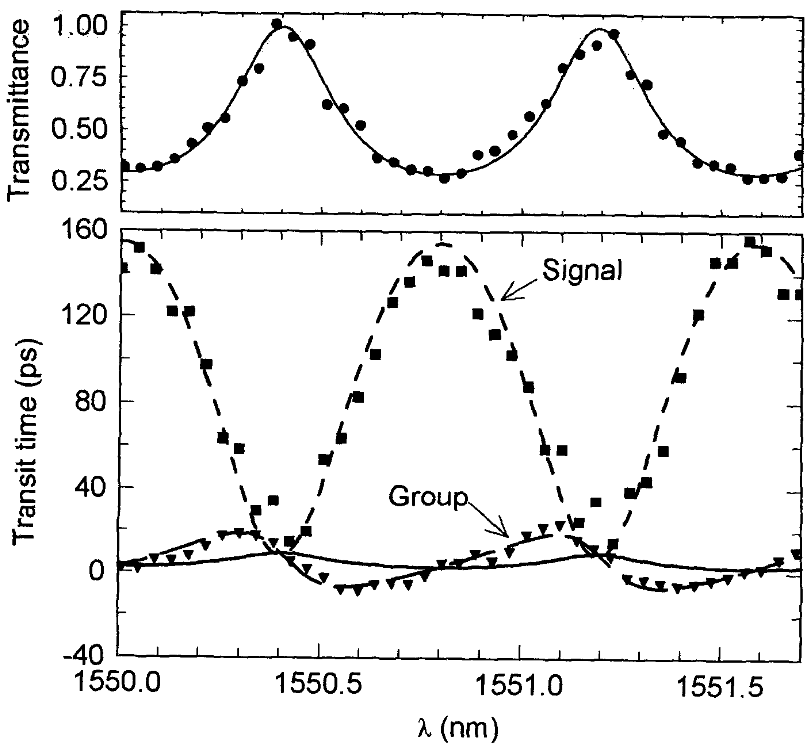

Fig. 1.

7. References

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