In order to study the possible phase conjugation of optical near-fields, it is necessary to go beyond the slowly varying envelope- and electric dipole approximations that are normally applied in phase conjugation studies where spatially non-decaying (or at least slowly decaying) modes are mixed. In the present dissertation a random-phase-approximation calculation of the nonlocal nonlinear optical response tensor describing the third order nonlinear current density generated by degenerate four-wave mixing in an inhomogeneous electron gas is established. The description is based on a semi-classical approach, in which the electromagnetic field is considered as a classical quantity, and the starting point is the equation of motion for the density matrix operator. The interaction Hamiltonian is taken in its minimal coupling form, and it includes the term in the current density operator which is proportional to the prevailing vector potential. Using this formalism the spatial structure of the optical response of the system is described in terms of the microscopic transition current densities. The calculation thus includes contributions originating from both the $\vec{p}\cdot\vec{A}$ and $\vec{A}\cdot\vec{A}$ terms in the interaction Hamiltonian. It is demonstrated that inclusion of the $\vec{A}\cdot\vec{A}$ term in the interaction Hamiltonian introduces some important phenomena that are conceptually different from those originating in the $\vec{p}\cdot\vec{A}$ part. To emphasize the physical meaning of the various processes, the couplings between observation points for the field and the current density is presented in a diagrammatic form. The result of an analysis of the tensor symmetries associated with the $\vec{p}\cdot\vec{A}$ and $\vec{A}\cdot\vec{A}$ interactions are summarized in terms of symmetry schemes for the phase conjugation process. The theoretical model is followed by a calculation of the phase conjugated response from a single-level metallic quantum well. The single-level quantum well represents the simplest possible configuration of a quantum-well phase conjugator. Furthermore, it is an interesting object, since its optical response contains no dipole terms. The discussion of the response is based on the use of light that is polarized either in the scattering plane or perpendicular to the scattering plane to excite the process. It is demonstrated that the phase conjugation process is extremely efficient in the evanescent regime of the wavevector spectrum. We address the problem of plane-wave excitation in the high wavenumber end of the evanescent regime and discuss the use of a broadband source to excite the process. One possible broad angular band source is a quantum wire, and the phase conjugated angular spectrum from a quantum wire is presented and discussed. The subwavelength size of the quantum wire makes it a possible candidate for discussion of confinement of light, and the confinement of light in two dimensions in front of a single-level metallic quantum-well phase conjugator is discussed. It is justified that by a proper choice of orientation of the current in the quantum wire a field compression substantially beyond the Rayleigh limit is obtained. The thesis is concluded with a short description of the more general case where the quantum well is allowed to have more than one energy eigenstate, and numerical results showing the response from a two-level quantum well as the phase conjugating medium are presented and discussed.

MED ET RESUMÉ PÅ DANSK.

ISBN 87-89195-16-7