Invited Paper

Modulating electro-absorption coefficient of impurity doped quantum dots driven by noise

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ABSTRACT

Present study carries out an extensive inspection of the profiles of *electro-absorption coefficient (EAC)* of doped *GaAs quantum dot (QD)* under the control of *Gaussian white noise*. A large number of important physical parameters has been varied over a range and the consequent changes in the EAC profiles have been thoroughly scrutinized. The said physical parameters comprise of electric field, magnetic field, confinement potential, dopant location, dopant potential, noise strength, aluminium concentration (only for $Al_xGa_{1-x}As$ alloy QD), carrier density, relaxation time, position-dependent effective mass (PDEM), position-dependent dielectric screening function (PDDSF), anisotropy, hydrostatic pressure (HP) and temperature. The particular physical quantity being varied, presence of noise and its pathway of application, together, lead to the appearance of diverse features in the EAC profiles. As a technologically meaningful aspect we often find maximization of EAC for some typical combinations as mentioned above. Presence of multiplicative noise, quite often, causes greater departure and greater suppression of EAC profiles from a noise-free condition than its additive counterpart. The outcomes of the study indicate prolific scope of harnessing EAC of doped QD systems in presence of noise by delicate adjustment of several control parameters.

1. Introduction

Prominent enhancement in the system confinement can be ensured if we make a trip from bulk materials to low-dimensional semiconductor systems (LDSS) e.g. quantum wells (QWLs), quantum wires (QWRs) and quantum dots (QDs). The enhanced confinement leads to noticeable changes in a number of properties such as energy spectrum, polarizability, electrical, optical and so on. LDSS are nowadays extensively used as chief ingredients in manufacturing high-performance microelectronic and optoelectronic devices. Besides such technological relevance, study of LDSS also refines our concept of basic physics.

Doping of impurity to LDSS changes its structural complexities through the modification of the confinement potential. This, in effect, influences various interactions functioning in the system giving rise to remarkable changes in the optical and other properties of LDSS. Nowadays, impurity doping in LDSS has emerged as a standard phenomenon and is subjected to full-fledged investigation [1–36].

Third-order nonlinear optical (NLO) effects provide the foundation for a number of technology-oriented applications related to high-capacity communication networks, in which ultrafast switching, signal regeneration and high-speed demultiplexing can be accomplished, all-optically [37]. Moreover, third-order nonlinearity also deems

importance in view of its ubiquitous applications in optoelectronic and photonic devices. As stated already, LDSS enjoy enormous hike in the third-order nonlinearity compared with the bulk materials [38], and, particularly, QDs exhibit large magnitude of third-order nonlinearity owing to its δ-like density of states. Thus, a large variety of LDSS-based materials are now widely recognized for showing noticeable third-order nonlinearities. However, for further progress, understanding the physical processes underlying this nonlinear response is a necessity. It comes out that the real and imaginary parts of the third-order optical susceptibility ($\chi^{(3)}$) are the physical quantities which are linked with the microscopic origin of nonlinearity [37]. Thus, various aspects of $\chi^{(3)}$ have been explored in detail by several authors [38–51].

Electro-absorption coefficient (EAC) or *electro-absorption frequency-dependent susceptibility* is a highly important third-order NLO quantity to study photoemission and detection applications of QDs [44]. It is possible to fine-tune and even maximize the magnitude and resonance wavelength of EAC by appropriate structural modification of QD [44]. Above facts have led to a substantial number of notable works that deal with EAC in LDSS [38,44–46,48–50].

The performance of devices consisting of LDSS heavily depends on presence of *noise*. Often noise comes out as an obstacle to various applications of these devices. Noise can be introduced to the system
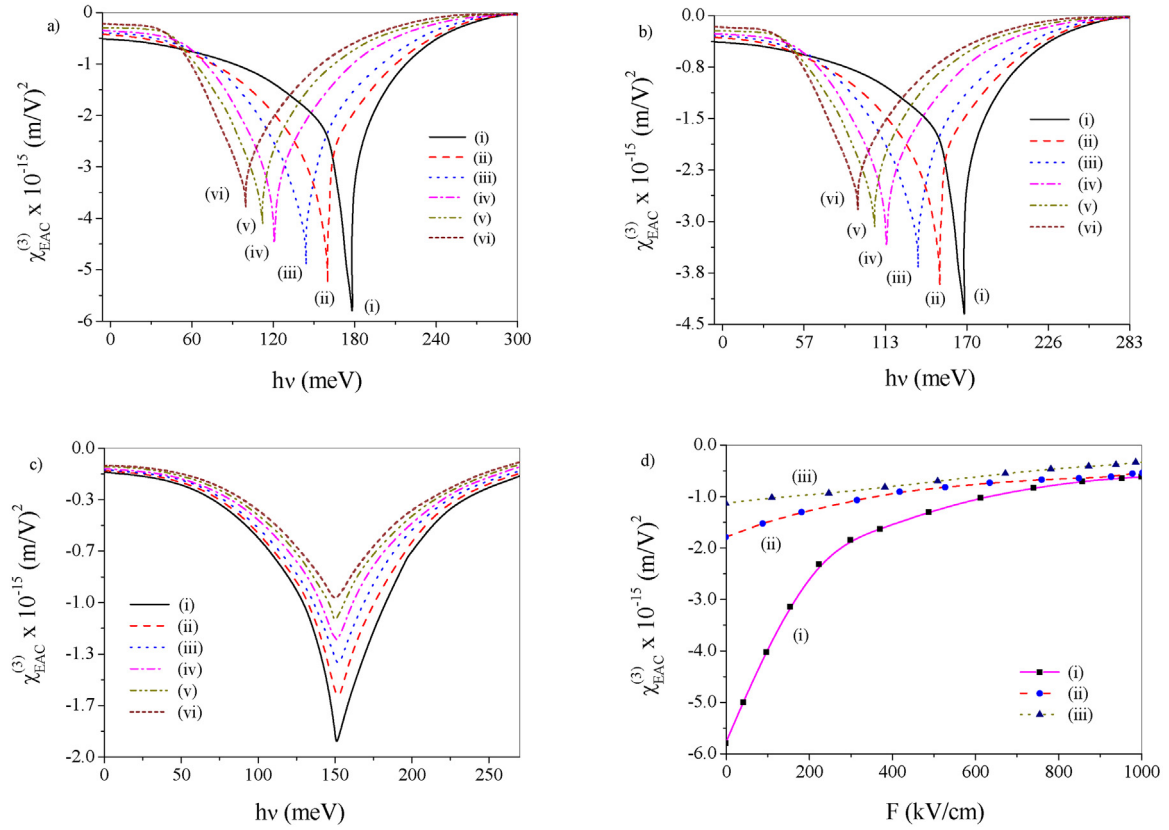

Fig. 1. Plots of $\chi_{EAC}^{(3)}$ against $h\nu$ for different values of F: (a) in absence of noise, (b) in presence of additive noise and (c) in presence of multiplicative noise. In these plots the values of F are (i) 0 kV/cm, (ii) 200 kV/cm, (iii) 400 kV/cm, (iv) 600 kV/cm, (v) 800 kV/cm and (vi) 1000 kV/cm, (d) plots of $\chi_{EAC}^{(3)}$ vs F at $h\nu = 177.0$ meV where (i) noise-free, (ii) additive noise applied and (iii) multiplicative noise applied.
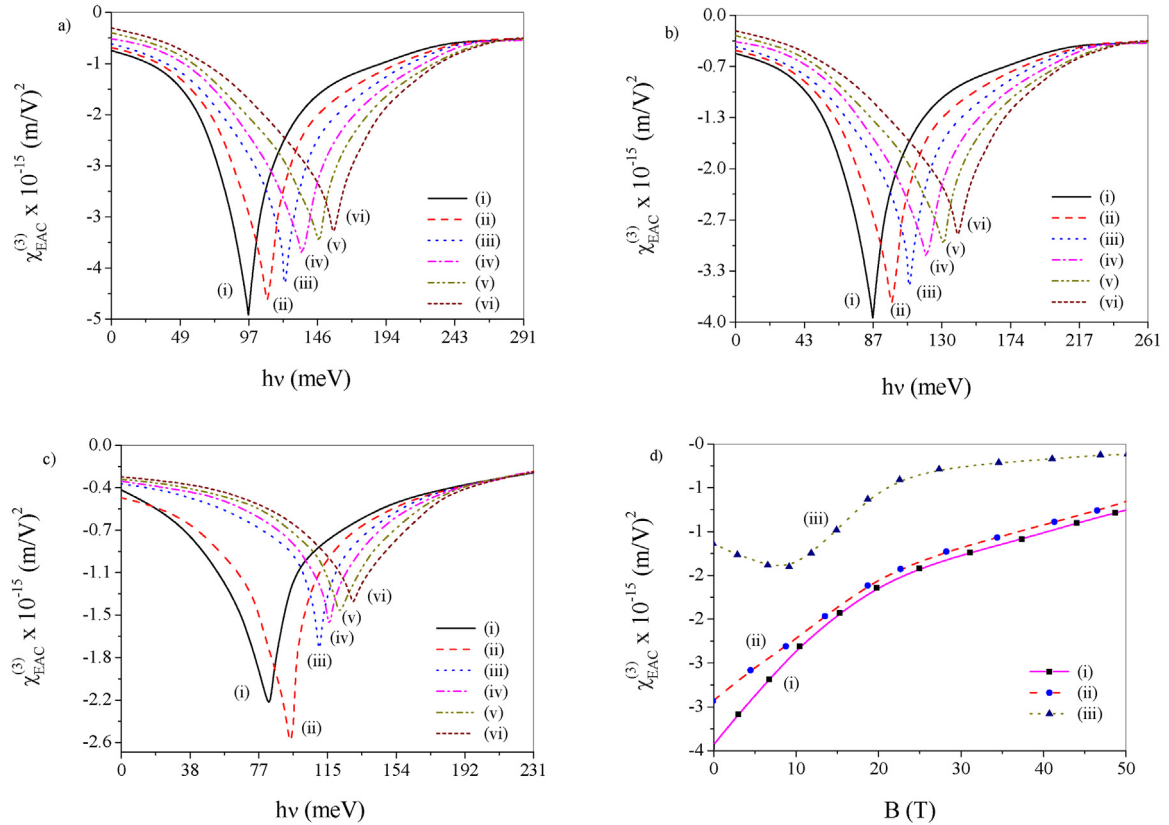

Fig. 2. Plots of $\chi_{EAC}^{(3)}$ against $h\nu$ for different values of B: (a) in absence of noise, (b) under applied additive noise and (c) under applied multiplicative noise. In these plots the values of B are (i) 0 T, (ii) 10 T, (iii) 20 T, (iv) 30 T, (v) 40 T and (vi) 50 T, (d) plots of $\chi_{EAC}^{(3)}$ vs B at $h\nu = 90.0$ meV where (i) noise-free, (ii) additive noise applied and (iii) multiplicative noise applied.