Gauge covariant Keldysh formulation of Wigner representation through deformational quantization NAOYUKI SUGIMOTO, Department of Applied Physics, University of Tokyo, SHIGEKI ONODA, NAOTO NAGAOSA, CREST, Department of Applied Physics, University of Tokyo — Non-linear responses such as nonlinear optical effects are of great current interests from the fundamental physics and application viewpoints. Therefore a microscopic quantum theory for these non-linear processes in non-equilibrium state is called for. The extension of the Kubo formula or the Keldysh formula to the nonlinear response preserving gauge-covariance is not straightforward. We developed a gauge-covariant Keldysh formulation with a general electromagnetic field[1]. Such a formulation is realized by replacing the Moyal product in the Wigner space by the star product which is given by deformational quantization. We derived the explicit form of this star product. Our formula has the following merits. (1) The star product facilitates an order-by-order calculation of an observable in terms of the electromagnetic field. (2) The gauge-invariance of the formula is clearly seen, and we do not have to worry about the Ward identity, because the formula is given by gauge-covariant Wigner space. We will mention about an application of this method to Zener tunneling problem in the presence of dissipation. [1] N. Sugimoto, S. Onoda and N. Nagaosa, cond-mat/0611142.

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