Properties of quarkonium states in moving thermal bath

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Introduction

Heavy quarkonium ($Q\bar{Q}$) states are considered as the most powerful probes in investigating the properties of the Quark Gluon Plasma (QGP), because they are the only hadronic states that are able to survive above the deconfinement temperature [1].

In recent years there has been a renewed interest in the properties of bound states moving in a thermal medium due to the advent of high energy heavy-ion colliders. The first study of the real part of the potential between heavy quark and heavy anti-quark pair moving with respect to the QGP was calculated in [2] by using a kinetic theory approach and later by using semiclassical transport theory in [3]. It was found that screening is reduced in the direction perpendicular of the moving parton but is increased in the direction of the moving parton. This leads to a modification of quarkonium suppression. Subsequent analyses have confirmed this effect and studied the formation of wakes in the QGP [4]. The properties of heavy quarkonium states moving across a homogeneous thermal bath has been studied in [5]. However these studies have considered only the perturbative part of the heavy quark potential. In this calculation, we have also considered non-perturbative term along with perturbatiive term. It is reasonable to study the effect of the string term above the deconfinement temperature (T_c) [6] due to the deviations from perturbative calculations and the ideal gas behavior beyond T_c. Recently one of us has derived the real and imaginary component of the potential in the presence of non-perturbative term using kinetic theory and thermal field theory approach [7] in a static medium. In this work we study the behavior of the real and imaginary part of the static heavy quark potential between a heavy quark and its anti-quarks, which are in relative motion with respect to the thermal bath. The heavy quark complex potential is obtained by correcting both the Coulombic and linear terms in the Cornell potential by the static limit of hard-loop resumed gluon propagator. Each potential term (real or imaginary) depends on the angle between the orientation of the dipole and the direction of motion of the thermal medium.

We calculate both the real and imaginary part of the potential for two particular cases: when heavy quarkonium state is aligned along and perpendicular to the direction of the moving thermal medium. An oscillation is observed in real part of potential when $Q\bar{Q}$ pair is in the direction of motion of the thermal medium, which leads to the formation of wake in the plasma. Imaginary part of the potential increases monotonically and approaches to zero with increase in velocity for parallel case. Both the real and imaginary part of the potential increases with the inclusion of the string term. It is important to discuss that whether the dissociation mechanism (screening versus Landau damping) remains the same when the bound state moves with respect to the thermal bath. Therefore we calculate the decay width from the imaginary part of the potential. The approximated solution of decay width in the

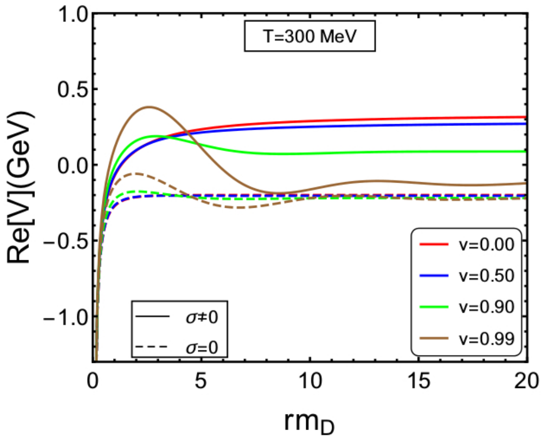

FIG. 1: Real part of the potential for various values of velocity at $T = 300$ MeV when quark anti-quark pair is parallel w.r.t the relative velocity between the dipole and the thermal medium.

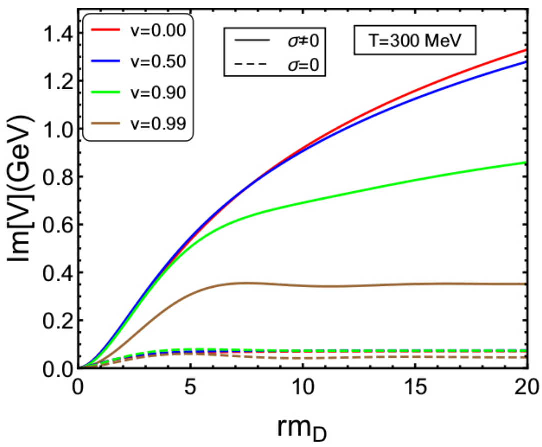

FIG. 2: Imaginary part of the potential for various values of velocity at $T = 300$ MeV when quark anti-quark pair is parallel w.r.t the relative velocity between the dipole and the thermal medium.

small velocity and small Debye mass limit:

$$\Gamma = \frac{m_D^2 T}{\sqrt{(1-v^2)}} \left(\frac{4}{\alpha m_Q^2} - \frac{12\sigma}{\alpha^4 m_Q^4} \right) \log \left(\frac{m_Q \alpha}{m_D} \right). \quad (1)$$

We found that decay width increases slowly with the increase in velocity and increase is more with the increase of velocity, which results in the modification of the quarkonium dissociation temperature.

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