A calculation of the thermal quark propagator is presented taking the gluon condensate above the critical temperature into account. The quark dispersion relation following from this propagator is derived.

As an alternative method to lattice and perturbative QCD we suggest to include the gluon condensate into the parton propagators. In this way non-perturbative effects are taken into account within the Green functions technique.

In the case of a pure gluon gas with energy density $\epsilon$ and pressure $p$ the gluon condensate can be related to the interaction measure $\Delta = (\epsilon - 3p)/T^4$ via

$$\langle G^2 \rangle_T = \langle G^2 \rangle_0 - \Delta T^4,$$

where $G^2 \equiv (11\alpha_s/8\pi) : G^a_{\mu\nu} G^a_{\mu\nu} :$ and $\langle G^2 \rangle_0 = (2.5 \pm 1.0) T_c^4$ is the zero temperature condensate. Here $G^a_{\mu\nu}$ is the field strength tensor and $T_c$ the critical temperature of the phase transition to the quark-gluon plasma (QGP).

At zero temperature the quark propagator containing the gluon condensate has been constructed already. Here we will extend these calculations to finite temperature.

The full quark propagator in the QGP can be written by decomposing it according to its helicity eigenstates

$$S(P) = \frac{\gamma_0 - \hat{p} \cdot \vec{\gamma}}{2D_+(P)} + \frac{\gamma_0 + \hat{p} \cdot \vec{\gamma}}{2D_-(P)},$$

where $D_\pm(P) = (-p_0 \pm p) (1 + a) - b$ and

$$a = \frac{1}{4p^2} \left[ tr (\not{P} \Sigma) - p_0 tr (\gamma_0 \Sigma) \right],$$

$$b = \frac{1}{4p^2} \left[ P^2 tr (\gamma_0 \Sigma) - p_0 tr (\not{P} \Sigma) \right].$$
Using the imaginary time formalism and expanding the quark propagator in Fig.1 for small loop momenta, i.e. $k \ll p$ and $k_0 = 2\pi n T = 0$, we obtain

$$a = -\frac{4}{3} g^2 T \int \frac{d^3 k}{(2\pi)^3} \left[ \left( \frac{1}{3} p^2 - \frac{5}{3} p_0^2 \right) k^2 \bar{D}_l(0, k) + \left( \frac{2}{5} p^2 - 2p_0^2 \right) k^2 \bar{D}_t(0, k) \right],$$

$$b = -\frac{4}{3} g^2 T \int \frac{d^3 k}{(2\pi)^3} \left[ \frac{8}{3} p_0^2 k^2 \bar{D}_l(0, k) + \frac{16}{15} p_0^2 k^2 \bar{D}_t(0, k) \right],$$

(4)

where $\bar{D}_{l,t}$ are the longitudinal and transverse parts of the non-perturbative gluon propagator at finite temperature in Fig.1.

The moments of the longitudinal and transverse gluon propagator in (4) are related to the chromoelectric and chromomagnetic condensates via

$$\langle E^2 \rangle_T = \langle : G_{0i}^a G_{0i}^a : \rangle_T = 8T \int \frac{d^3 k}{(2\pi)^3} k^2 \bar{D}_l(0, k),$$

$$\langle B^2 \rangle_T = \frac{1}{2} \langle : G_{ij}^a G_{ij}^a : \rangle_T = -16T \int \frac{d^3 k}{(2\pi)^3} k^2 \bar{D}_t(0, k).$$

(5)

These condensates can be extracted from the expectation values of the space-and timelike plaquettes $\Delta_{\sigma,\tau}$ computed on the lattice, using

$$\frac{\alpha_s}{\pi} \langle E^2 \rangle_T = \frac{4}{11} \Delta_{\tau} T^4 - \frac{2}{11} \langle G^2 \rangle_0,$$

$$\frac{\alpha_s}{\pi} \langle B^2 \rangle_T = -\frac{4}{11} \Delta_{\tau} T^4 + \frac{2}{11} \langle G^2 \rangle_0.$$  

(6)

The quark dispersion relation describing collective quark modes in the QGP in the presence of a gluon condensate, follows from $D_\pm(P) = 0$. Using the lattice results for the plaquette expectation values they have been determined numerically and are shown in Fig.2 for various temperatures.

The dispersions exhibit two massive quark modes. The upper branch comes from the solution of $D_+ = 0$ and the lower one from $D_- = 0$. The lower branch, showing a minimum, corresponds to a so-called plasmino, possessing a negative ratio of helicity to chirality, and is absent in the vacuum.
At $p = 0$ both modes start from a common effective quark mass, which is given by $m_{\text{eff}} = [(2\pi \alpha_s/3)(\langle E^2 \rangle_T + \langle B^2 \rangle_T)]^{1/4}$. In the temperature range $1.1T_c < T < 4T_c$ we found approximately $m_{\text{eff}} = 1.15T$.

The qualitative picture of this quark dispersion relation is very similar to the one found perturbatively in the HTL limit. The main difference is the different effective mass, which is given by $m_{\text{eff}} = gT/\sqrt{6}$ in the HTL approximation.

As a possible application of this effective quark propagator we mention the computation of the photon and dilepton production rates from the QGP. For this purpose the photon self energy using effective quark propagators should be evaluated.

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