



Entanglement temperature with Gauss–Bonnet term

Shesansu Sekhar Pal^{a,*}, Sudhakar Panda^{b,1}

^a Department of Physics, Utkal University, Bhubaneswar 751004, India

^b Institute of Physics, Sachivalaya Marg, Bhubaneswar 751005, India

Received 26 March 2015; received in revised form 4 July 2015; accepted 21 July 2015

Available online 23 July 2015

Editor: Herman Verlinde

Abstract

We compute the entanglement temperature using the first law-like of thermodynamics, $\Delta E = T_{ent} \Delta S_{EE}$, up to Gauss–Bonnet term in the Jacobson–Myers entropy functional in any arbitrary spacetime dimension. The computation is done when the entangling region is the geometry of a slab. We also show that such a Gauss–Bonnet term, which becomes a total derivative, when the co-dimension two hypersurface is four dimensional, does not contribute to the finite term in the entanglement entropy. We observe that the Weyl-squared term does not contribute to the entanglement entropy. It is important to note that the calculations are performed when the entangling region is very small and the energy is calculated using the normal Hamiltonian.

© 2015 Published by Elsevier B.V. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>). Funded by SCOAP³.

1. Introduction and summary

The recent study of entanglement entropy has drawn a lot of attention because of its remarkable similarity with the black hole entropy [1]. The entanglement entropy is defined as von Neumann entropy: $S = -\text{Trace}_A(\rho_A \log \rho_A)$, where ρ_A is the reduced density matrix. For a spherical surface of radius, $\mathcal{R}$, the reduced density matrix is defined by tracing out the degrees of freedom that sits inside this radius, which is the complement of A . In which case, the von Neu-

* Corresponding author.

E-mail addresses: shesansu@gmail.com (S.S. Pal), panda@iopb.res.in (S. Panda).

¹ On leave from HRI, Allahabad.

mann entropy depends on the area of the spherical region, $S \sim \mathcal{R}^2$. This von Neumann entropy is interpreted as the entropy seen by an observer sitting outside the radius $\mathcal{R}$.

In the context of gauge-gravity duality [2], a prescription, strictly speaking a conjecture, is suggested by Ryu and Takayanagi (RT) [3] to calculate the von Neumann entropy in the gravitational side. This von Neumann entropy is called as entanglement entropy. The RT prescription suggests to consider a co-dimension two spatial hypersurface in a way such that its boundary coincides with the boundary of the region that we are interested in and then find out the area of the minimal surface. Finally, the entanglement entropy is the ratio between the area and $4G_N$, where G_N is the Newton's constant (for recent reviews, see [4–6]). A claim of the proof of the RT conjecture is provided in different spacetime dimensions and with different entangling region in [7,8]. The subadditivity nature of the entanglement entropy is shown in [9].

In this paper, we shall report the result of a holographic calculation of the entanglement entropy of a given region upon inclusion of the terms up to Gauss–Bonnet term in the Jacobson–Myers (JM) entropy functional [10] in any arbitrary spacetime dimension. The shape of the entangling region that we are interested in is that of the slab type. To recall, the prescription that we shall follow to carry out such a calculation is that given by Ryu and Takayanagi (RT) [3], of course without the higher derivative term.

The JM entanglement entropy functional up to four derivative term is

$$4G_N S_{EE} = \int d^{d-1} \sigma \sqrt{\det(g_{ab})} \left[1 + \lambda_1 R(g) + \Lambda \left(R^2(g) - 4R_{ab}(g)R^{ab}(g) + R_{abcd}(g)R^{abcd}(g) \right) \right], \quad (1)$$

where λ_1 and Λ are unknown real coupling constants and are dimension full. A derivation of the JM functional starting from the Einstein–Hilbert action with the higher derivative terms are given in [11–13]. For our purpose, we do not require the full derivation of it.

The induced metric on the co-dimension two hypersurface is denoted as $g_{ab} = \partial_a X^M \partial_b X^N G_{MN}$, where G_{MN} is the $d+1$ dimensional bulk spacetime geometry and the hypersurface is described by X^M . The precise form of the hypersurface that follows [14,15]

$$\begin{aligned} \mathcal{K}^S + \lambda_1 \left(R\mathcal{K}^S - 2R^{ab}\mathcal{K}_{ab}^S \right) + \Lambda \left[\mathcal{K}^S \left(R^2 - 4R_{ab}R^{ab} + R_{a_1b_1c_1d_1}R^{a_1b_1c_1d_1} \right) - \right. \\ \left. 4RR^{ab}\mathcal{K}_{ab}^S + 8R^{abcd}R_{cd}\mathcal{K}_{ab}^S - 4R^{aecd}R_{ecd}^b\mathcal{K}_{ab}^S + 8R^a{}_cR^{bc}\mathcal{K}_{ab}^S \right] = 0, \end{aligned} \quad (2)$$

which is essentially the equation of motion associated to the field X^S and $\mathcal{K}^S \equiv g^{ab}\mathcal{K}_{ab}^S$, whose precise form $\mathcal{K}_{ab}^S = \partial_a \partial_b X^S - \gamma_{ab}^c \partial_c X^S + \partial_a X^M \partial_b X^N \Gamma_{MN}^S$, where γ_{ab}^c and Γ_{MN}^S are the affine connections defined using the induced metric g_{ab} and the bulk geometry, G_{MN} , respectively. This particular form of the hypersurface holds good irrespective of the shape and size of the entangling region.

Let us note that without the higher derivative terms the equation of the hypersurface is derived earlier in [16] and is called as the extremal surface. In what follows, we shall be interested in the strip type entangling region only.

In this paper, we shall compute the correction to the expression of the RT entanglement entropy by considering such higher derivative terms in the JM functional. This essentially means

Download English Version:

<https://daneshyari.com/en/article/1840439>

Download Persian Version:

<https://daneshyari.com/article/1840439>

[Daneshyari.com](https://daneshyari.com)