Time-Domain Thermoreflectance (TDTR) Measurements of the Thermal Conductivity Tensor Using an Elliptical-Beam Method

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We developed a new approach for measuring the thermal conductivity tensor in transversely anisotropic materials by using a highly elliptical pump beam in the time-domain thermoreflectance (TDTR) method. The shape and the orientation of the elliptical pump beam are controlled by using a pair of cylindrical lenses. The highly elliptical pump beam induces a one-dimensional temperature profile on the sample surface that has a fast decay along the short axis of the pump, hence the direction of the heat flux. The detected TDTR signal is exclusively sensitive to the in-plane thermal conductivity along the heat flux direction. By rotating the orientation of the elliptical pump beam (or equivalently rotating the sample) and conducting the TDTR measurements as a function of delay time between the pump and the probe, we can derive the full thermal conductivity tensor of the sample. As a demonstration of our elliptical-beam TDTR approach, we measured the thermal conductivity tensor of ZnO (11-20) and TiO_2 (100) using a pump beam with an aspect ratio of 4:1. The measured results agree very well with the literature values. A comparison between our elliptical-beam TDTR approach and an alternative beam-offset TDTR approach is made to showcase their pros and cons in measuring the thermal conductivity of transversely anisotropic materials.