We introduce a method for laboratory measurements of the velocities and polarizations of the compressional and shear waves in rock samples. The method consists of measuring time dependent displacement of a particular point on the surface of the sample in three independent directions by a laser Doppler interferometer. The high accuracy of these measurements allows straightforward determination of the polarization, and identification of the wave type. These measurements can be inverted to estimate the complete stiffness tensor of anisotropic rock samples. We demonstrate that such a method can constrain the estimates of anisotropy better than more conventional time-of-flight methods. This is illustrated by a “walk away” laboratory experiment on a sample of a strongly anisotropic material. The method can be extended to measurements under stress by using a high-pressure cell made of material transparent to laser beam.