High-power testing of optical components for LIGO

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The LIGO (laser interferometer gravitational-wave observatory) detector is a complex Fabry-Perot/Michelson interferometer, designed to detect gravitational waves (GW) from astrophysical sources. When a GW strikes the detector, the underlying space will be extended in one direction and contracted in the orthogonal direction. The LIGO detector is designed to detect this space-strain, as a relative change in the lengths of the mutually orthogonal arms. Because this strain is much smaller than the arm length (typically 1 part in 1021), each arm is in the form of an optical resonator, effectively increasing the arm length and, hence, its change for a given strain. The arm-length change is measured as the relative phase shift at the beam splitter. To cope with the tiny phase shift, LIGO detects it as a beat signal between a carrier frequency and a side band frequency at the signal port (also called the dark port) of the Michelson interferometer. The side band is generated by phase-modulating the carrier frequency; the modulation frequency is chosen, so that the side band is far off resonance with the resonators in the arms, while the carrier frequency is on resonance. In this way, the phase shift associated with a relative arm-length change can be detected as amplitude modulation at the modulation frequency.