the case of black-hole binaries with $M_1 \sim 100\text{–}1000\, M_\odot$ or $M_1 \gtrsim 10^6\, M_\odot$ (Fig. 9.4). In the Newtonian regime, if we orient the polarization axes $\vec{e}_{x'}$ and $\vec{e}_{y'}$ along the major and minor axes of the projection of the orbital plane on the sky, then the wave form will be

$$h_+ = 2(1+\cos^2 \iota)(\mu/r)(\pi M f)^{\frac{2}{3}} \cos(2\pi f t), \tag{42a}$$

$$h_\times = \pm 4 \cos \iota(\mu/r)(\pi M f)^{\frac{2}{3}} \sin(2\pi f t). \tag{42b}$$

Here it is assumed that the orbit is circular because radiation reaction long ago will have forced circularization (Peters and Mathews, 1963); ι is the angle of inclination of the orbit to the line of sight; M and μ are the total and reduced masses

$$M = M_1 + M_2, \qquad \mu = M_1 M_2 / M; \tag{42c}$$

and f, the frequency of the waves (equal to twice the orbital frequency), is given as a function of time by (MTW equation (36.17))

$$f = \frac{1}{\pi}\left[\frac{5}{256}\frac{1}{\mu M^{\frac{2}{3}}}\frac{1}{(t_o - t)}\right]^{\frac{3}{8}}. \tag{42d}$$

The most promising detectors for coalescing neutron-star binaries and low-mass black-hole binaries are beam detectors in the planned multi-kilometer LIGOs. As we shall see in Section 9.5.3(e), a beam detector can be operated in several different optical configurations. The optimum configuration for searching for coalescing binaries is likely to be one with *light recycling*, for which the spectral density of shot noise (the dominant noise above some 'seismic cutoff' frequency f_s) will have the form

$$S_h(f) = \text{const} \times f_k[1 + (f/f_k)^2] \quad \text{at } f > f_s. \tag{43a}$$

Here f_k is a 'knee frequency' which the experimenters can adjust by changing the reflectivities of certain mirrors in their detectors; see equation (117c) and Fig. 9.13 below, and associated discussion. The constant in equation (43a) is independent of the choice of f_k. At frequencies below the 'seismic cutoff' f_s seismic noise is likely to come on very strong; accordingly, we shall make the approximation

$$S_h(f) = \infty \quad \text{for } f < f_s. \tag{43b}$$

By Fourier-transforming the wave forms (42), squaring, and averaging over the source orientation angle ι, we obtain

$$\langle |\tilde{h}_+|^2 + |\tilde{h}_\times|^2 \rangle = \frac{\pi}{12}\left(\frac{\mu}{r}\right)^2 \frac{M^3}{\mu} \frac{1}{(\pi M f)^{\frac{7}{3}}}. \tag{44}$$

By inserting this source strength (44) and the detector noise (43) into equation (30) and maximizing the resulting signal-to-noise ratio with