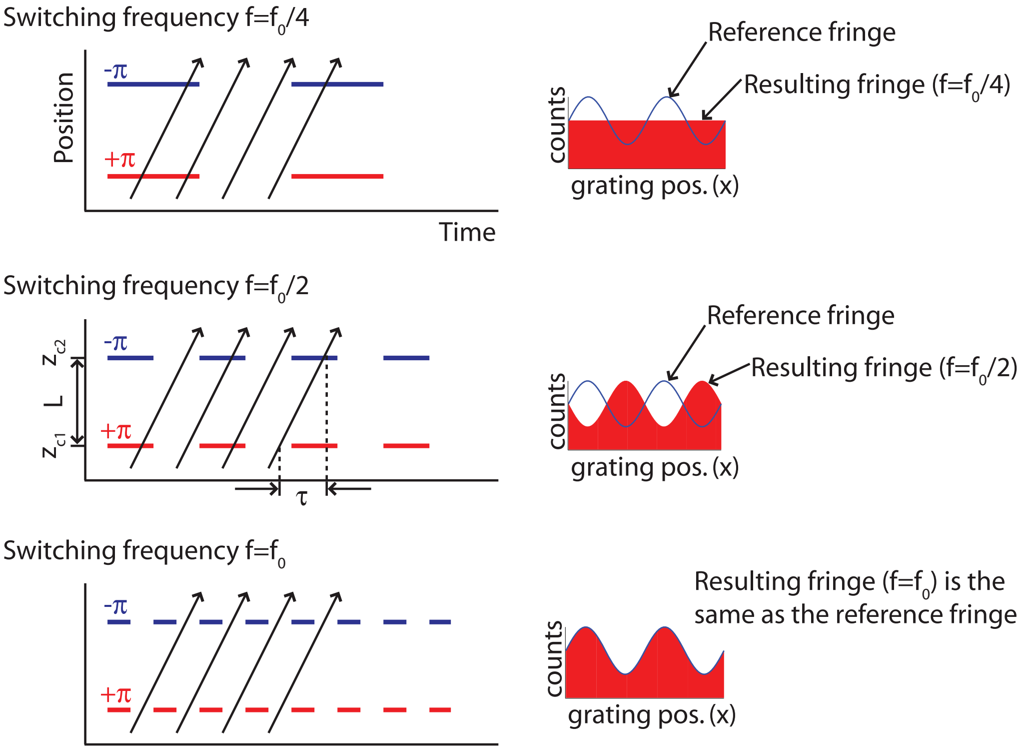

Figure 1. Atoms with different starting times will acquire 0, $+\pi$ (red) or $-\pi$ (blue) phase shifts as they pass through choppers 1 and 2, depending on their velocity v and the chopping frequency f. The time it takes an atom with velocity v to travel the distance L between the choppers is τ and $f_0 = 1/\tau$. We measure the average of the sinusoidal probability distributions formed by each atom interfering with itself, shown at the right. The reference interference pattern with the choppers off is shown in blue and the resulting interference patterns with the choppers on are shown in red.

particular frequencies. Before turning on the phase choppers, the atom interference pattern is given by $\langle N\rangle(1 + C_0 \sin(kx + \phi_0))$, where $\langle N\rangle$ is the average flux, C_0 is the reference contrast and ϕ_0 is the reference phase. This interference pattern represents a sum of the sinusoidal probability distributions of each detected atom (see [13, 14] for additional information). Depending on its start time and velocity and the chopping frequency, an atom will pass through the choppers in one of four possible pairs of conditions (off–off, on–off, off–on or on–on) and produce a probability distribution phase-shifted by an amount equal to the sum of the differential phase shifts applied by each phase chopper. For clarity, we specify the differential phase shift from chopper 1 to be π, the differential phase shift from chopper 2 to be $-\pi$, and the duty cycle to be 50%; however, we stress that phase choppers still enable velocity measurements when using other phase shifts and duty cycles. We now describe what happens to the interference pattern created by atoms with a single velocity v when the choppers are switched at four particular frequencies (see figure 1):

- $f \ll f_0$. Atoms experience the off–off (0 net differential phase shift) or on–on (0 net differential phase shift) pairs of conditions with equal likelihood, and all atoms emerge with 0 net phase shift. The contrast and phase of the detected ensemble remain unchanged.