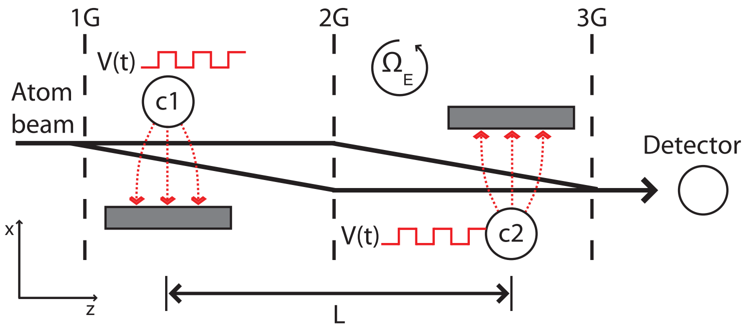

Figure 2. Nanogratings 1G, 2G and 3G form a Mach–Zehnder interferometer. Two phase choppers (c1 and c2) are placed a distance $L = 1270.68(25)$ mm apart. A voltage $V(t)$ applied across the choppers creates an electric field (dashed lines). Atoms with velocity v passing through choppers 1 and 2 acquire net differential phase shifts $\phi_1(t) + \phi_2(t + L/v)$. The Earth rotation rate Ω_E modifies the measured contrast and phase via the Sagnac effect, especially for slow beams. A hot-wire detector counts the atoms. Diagram not to scale.

3. Experimental design

Before describing in detail how the phase choppers enable velocity measurements, we briefly review our atom interferometer and the construction of the phase choppers. We use three 100 nm period nanogratings to diffract a supersonic beam of atoms and create a Mach–Zehnder interferometer (see figure 2). An atom diffracted by the first and second gratings will be found with a sinusoidal probability distribution at the plane of the third grating. The third grating acts as a mask of this interference pattern. We measure the flux as a function of grating position to determine the phase and contrast of the fringe pattern. The gratings are each separated by 940 mm. We detect $\langle N \rangle \approx 10^5$ atoms s^{-1} with a typical contrast of $C_0 \approx 25\%$ using a hot-wire detector 0.5 m beyond the third grating. See [1, 13, 14] for additional information.

We implemented phase choppers with electric field gradients switched on and off at a frequency f ranging from 0 to 30 kHz. We create the electric field gradient by periodically applying a voltage $V(t)$ of 1–5 kV to a $D = 1.57$ mm diameter copper wire at a distance $a = 1$ mm from a grounded aluminum strip. See [11], figure 3 for a schematic of the phase chopper. The high voltage is switched on and off in less than 200 ns with a DEI PVX-4130 pulse generator controlled by an SRS DS345 function generator. We place chopper 1 at a distance of approximately 300 mm after the first grating (and chopper 2 at a similar distance before the third grating). We measured the chopper 1 to chopper 2 distance as $L = 1270.68(25)$ mm. Two translation stages allow us to move the choppers perpendicular to the beam.

An atom with velocity v passing through the 1 mm gap in phase chopper i will acquire a differential phase shift

$$\phi_i(v, t) = c\frac{\alpha V(t)^2}{v}\frac{s(v)(2x_{0i} + s(v))}{(b^2 - x_{0i}^2)(b^2 - (x_{0i} + s(v))^2)}, \tag{3}$$

where $c = 8\pi^2 b/h \ln^{-2}((a + D/2 + b)/(a + D/2 - b))$, α is the atomic polarizability, v is the velocity of the atom, x_0 is the beam position relative to the ground plane, m is the mass of the atom, $b = a\sqrt{1 + D/a}$, $s(v) = hL_{gc}/mvd_g$ is the path separation at the chopper, d_g is the