Supplementary Information

Experimental test of Babinet's Principle in matter-wave diffraction

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I. FABRICATION AND CHARACTERIZATION OF THE DIFFRACTION GRATINGS

The reflection gratings used in this work were fabricated at UNIST, Korea using standard photolithography techniques. Each reflection grating consists of a 50-mm-wide microstructured array of 4-mm-long and 1.1-μm-thick parallel strips of photoresist patterned on a commercial gold mirror (Thorlabs PFSQ20-03-M03). The nominal period is $d = 400$ μm for every grating, while the nominal strip width a ($d - a$ for the complementary gratings), indicated in Fig. 1(b), varies from 10 to 390 μm.

The fabrication steps included spin-coating of the photoresist (AZ 5214E, AZ Electronic Materials) onto the gold mirror at 4000 rpm and a soft bake at 105 C for 90 s. Then, the coated mirror was exposed to UV radiation (365 nm) at 100 mJ/cm^2 through a photomask using a mask aligner (MA6, Suss MicroTec) and immersed to a developer (MIF 300, AZ Electronic Materials). The thickness of the grating strips can be controlled by varying the spin coating speed (ω) as it scales with $1/\sqrt{\omega}$. The actual strip thickness was measured to be 1.10 ± 0.01 μm by a surface profilometer (P6, KLA Tencor). The photoresist was completely removed between the strips by the developer during the standard photolithography process. We confirmed by optical microscopy that AZ 5214E exposed to UV was fully developed in MIF 300.

We do not expect any significant charge accumulation to occur in our gratings, wich could, potentially, perturb the diffraction of He atoms. Such an effect was reported for the diffraction of polyatomic molecules by silicon nitride gratings fabricated by Focused Ion Beam and Reactive Ion Etching techniques [1]. In contrast to the photolithographic making of our gratings, those methods are prone to result in charge accumulation. In addition, the He atom, due to its poor polarizability, is far less susceptible to electric field effects from charge accumulation than polyatomic molecules.

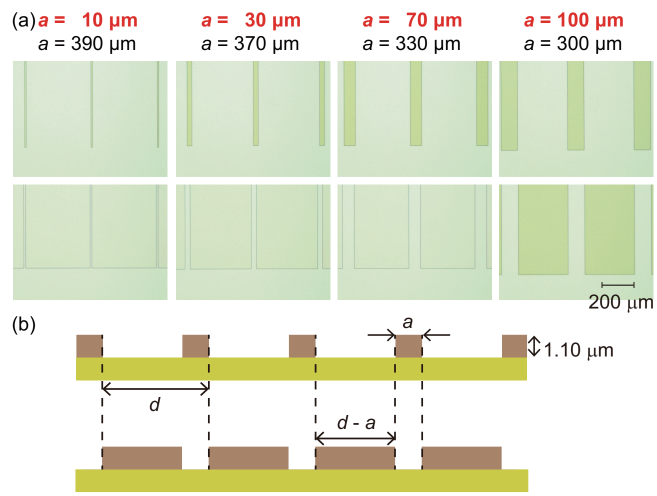

FIG. 1. (color online) (a) Microscope images of all 4 pairs of complementary gratings used in this work. The nominal strip widths a are indicated in red for the top row and in black for the bottom row pictures. Each micrograph shows a small area of 939 μm (horizontal) by 705 μm (vertical). As a result, only up to three strips are visible in each micrograph. (b) Schematic cross sectional view of a grating (upper part) and its complementary counterpart (lower part) indicating the thickness of the strips (1.10 μm) and the definitions of the period d and strip width a.

Figure 1(a) shows optical microscope images of all eight gratings used. From these images we measured the period and strip width for each grating. The results, listed in Table I, indicate slight deviations from the nominal values. For instance, the measured period d is between 402.6 μm and 402.8 μm for all gratings, i.e. it is consistently 0.7% larger than the nominal period of 400 μm. It is not known if this discrepancy is caused by an inaccuracy of the lithography mask or by an inaccurate microscope calibration. In addition, the measured slit widths exhibit systematic deviations from their nominal values. With decreasing strip width the measured widths of narrow strips ($a \leq 100$ μm) are found to be increasingly smaller than the nominal widths. For wide

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TABLE I. Strip widths and periods of all 8 gratings used in this work as measured with an optical microscope (Leica Microsystems DM4000 M). The nominal period of all of the gratings is $d = 400$ μm. The measured periods are $d = 402.7\,\mu$m. The nominal width a is given for each grating. The measured slit widths are printed in bold with the standard deviation given at the significant digit in brackets. The slit width ratios r_a are dimensionless. Slit widths and periods are given in μm.

Pair no.		1	2	3	4
Grating	Nominal strip width	$a = 10\,\mu$m	$a = 30\,\mu$m	$a = 70\,\mu$m	$a = 100\,\mu$m
	Strip width	**9.3(2)**	**29.4(2)**	**69.9(3)**	**100.1(3)**
	Period	402.7(3)	402.7(2)	402.6(3)	402.8(4)
Complementary Grating	Nominal strip width	$a = 390\,\mu$m	$a = 370\,\mu$m	$a = 330\,\mu$m	$a = 300\,\mu$m
	Strip width	**392.1(4)**	**372.0(3)**	**331.6(3)**	**301.0(4)**
	Period	402.8(3)	402.8(3)	402.8(3)	402.7(4)
Nominal strip widths ratio r_a		39.00	12.33	4.71	3.0
Strip widths ratio r_a		42.2(9)	12.63(8)	4.74(2)	3.00(1)

strips ($a \geq 300\,\mu$m), on the other hand, with increasing strip width the measured values appear increasingly larger than the nominal values. As a result, the deviations are most significant for the most asymmetric pair of complementary gratings; the measured strip width ratio $r_a = 42.2$ is 8.2% larger than the nominal value of $r_a = 39$.

[1] C. Brand, J. Fiedler, T. Juffmann, M. Sclafani, C. Knobloch, S. Scheel, Y. Lilach, O. Cheshnovsky and M. Arndt, *Annalen der Physik*, 2015, **527**, 580–591.