

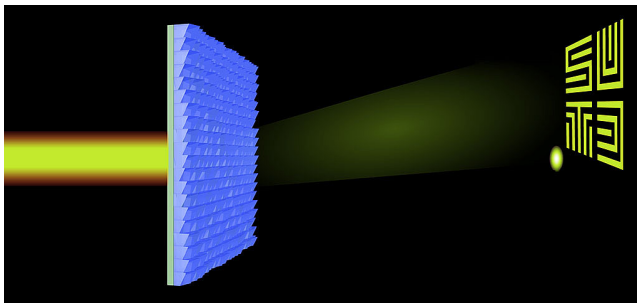
LACENET — A machine learning approach for mask generations for matter-wave lithography

Johannes Fiedler

UNIVERSITY OF BERGEN



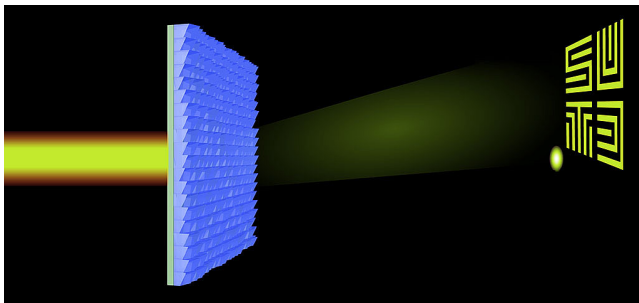
Lithography



<https://www.nanoscribe.com/en/news-insights/news/off-axis-holography-by-additive-microfabrication>



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Question: Which mask is needed to create a certain target pattern?



Matter-wave lithography



Matter-wave lithography

- Adaptation to matter waves (wave-particle duality)

Phys. Rev. Applied **11**, 024009 (2019).



Matter-wave lithography

- Adaptation to matter waves (wave-particle duality)
- Considering matter wave (particles)
Dielectric masks (solids)

- Question: Which mask is needed to create a certain target pattern?

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Outline

- 1 Interaction between atoms and dielectric masks**
- 2 Inversion of matter-wave propagation**
- 3 LACENET**



Forward propagation



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- Kirchhoff diffraction

$$P(\mathbf{r}) = \int d^2r^\ell g(\mathbf{r}; \mathbf{r}^\ell) t(\mathbf{r}^\ell) g(\mathbf{r}^\ell; \mathbf{r}_0)^2$$



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- Matter waves (single slit)

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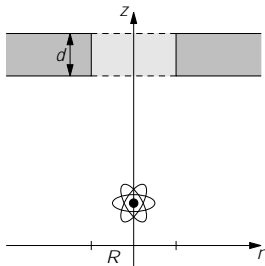
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Interaction between atoms and dielectric masks



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¹JF, Holst. B. J. Phys. B: At. Mol. Opt. Phys. **55**, 025401 (2022).



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- Theoretical model for total propagation

$$P(r) = \int_P d^2r^0 g(r; r^0) \exp \left[i \int_B d^2r^{00} \varphi(r^0; r^{00}) \right] \int d^3r^0 g(r^0; r_0)$$

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Impact of interactions on double slit

JF et al. Realistic mask generation for matter-wave lithography via machine learning, in preparation
<https://arxiv.org/abs/2207.08723>

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3. Hoping that the network learns and generalises

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N-slit interference

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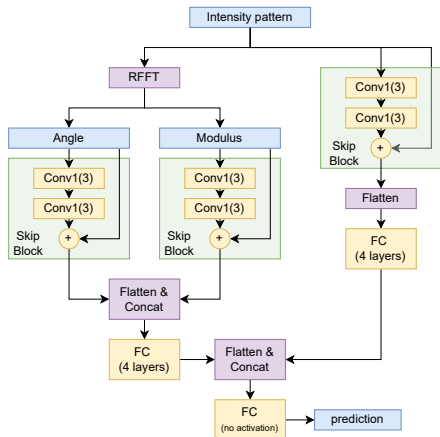
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Let's generate data...



LACENET architecture

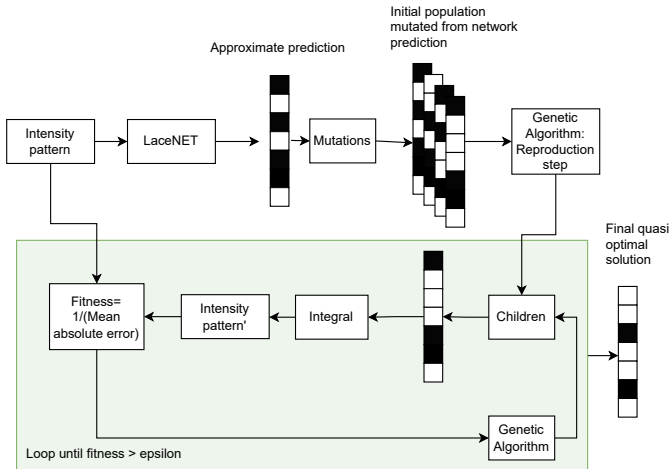


- Input P , output t
- Fourier transform P : split into amplitude and phase
- Fully connected layers and convolution layers

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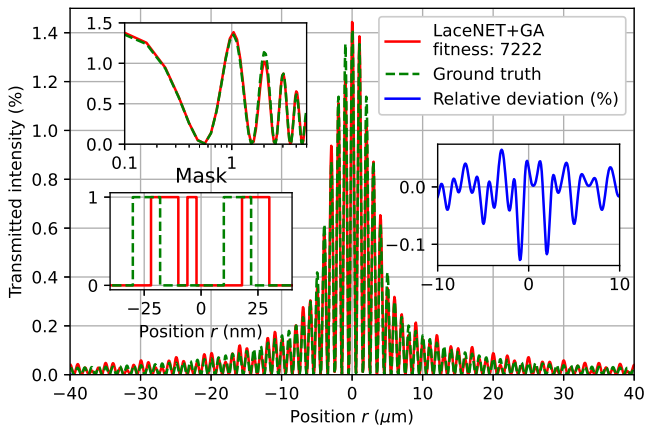
Network architecture



JF *et al.* Realistic mask generation for matter-wave lithography via machine learning, in preparation <https://arxiv.org/abs/2207.08723>



Double slit results



JF *et al.* Realistic mask generation for matter-wave lithography via machine learning, <https://arxiv.org/abs/2207.08723>



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- Purpose of nano-structuring surfaces:
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- Machine learning works!
- Purpose of nano-structuring surfaces:
 - Larger variety of patterns
 - Increase resolution
- Consequences/Future tasks:
 - Realistic source (velocity distribution, extension of source, ...)
 - Leaving Fraunhofer regime (! slowing forward propagation)
 - Handling big data



Thank you for your attention!

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