Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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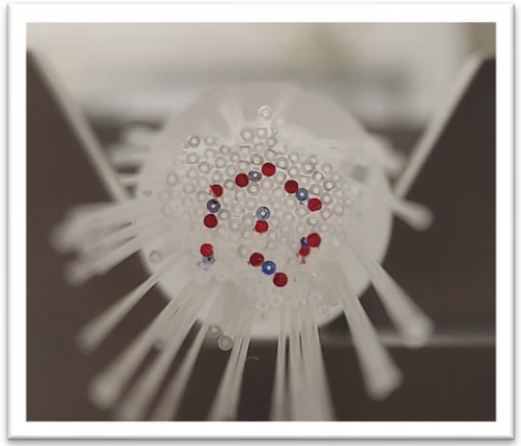
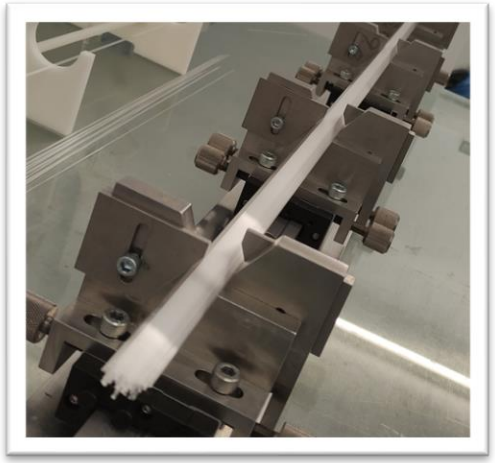
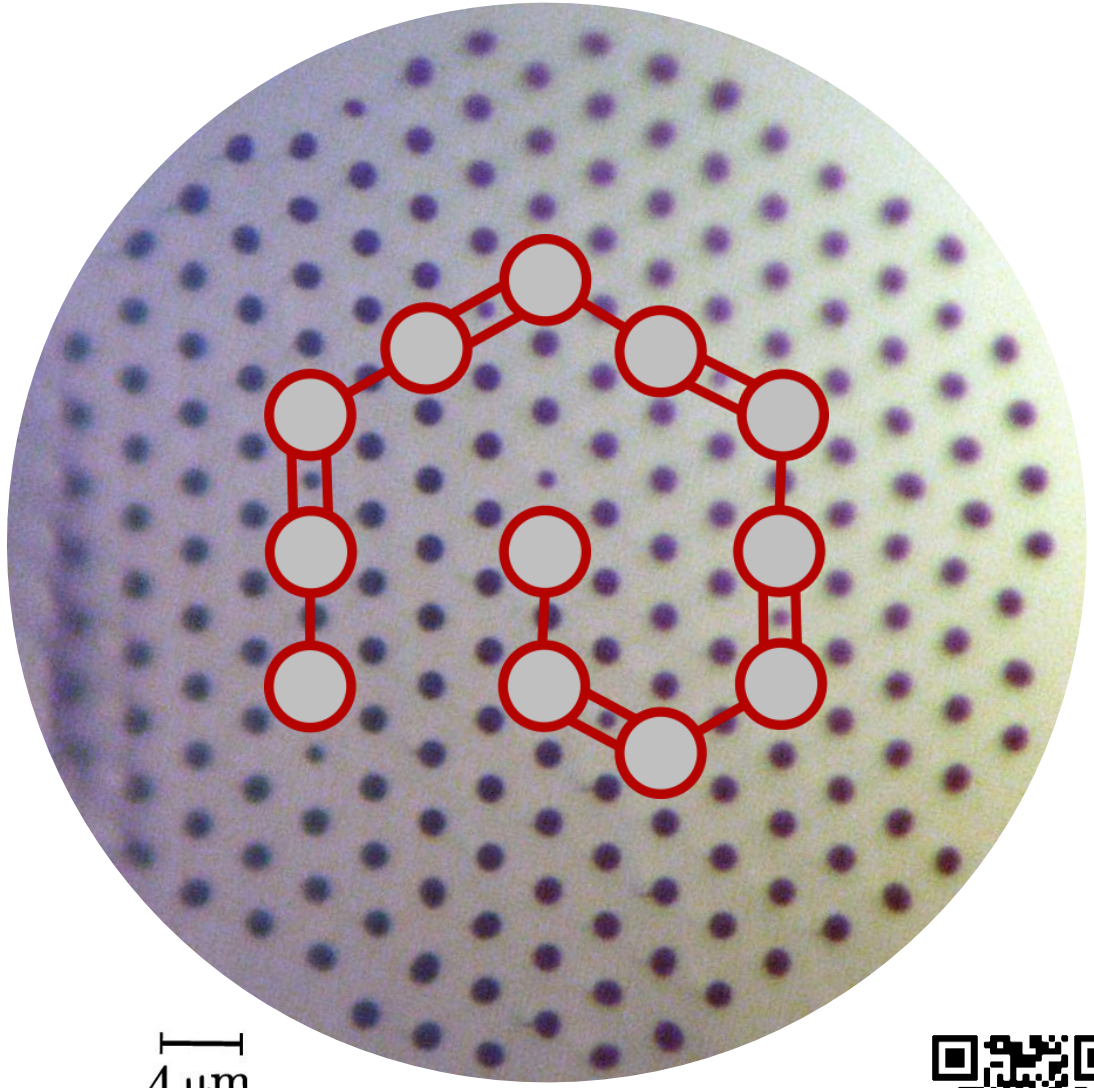
Topological Optical Fibre

Nathan Roberts, Guido Baardink, Josh Nunn,
Peter J Mosley, Anton Souslov

University of Bath, UK







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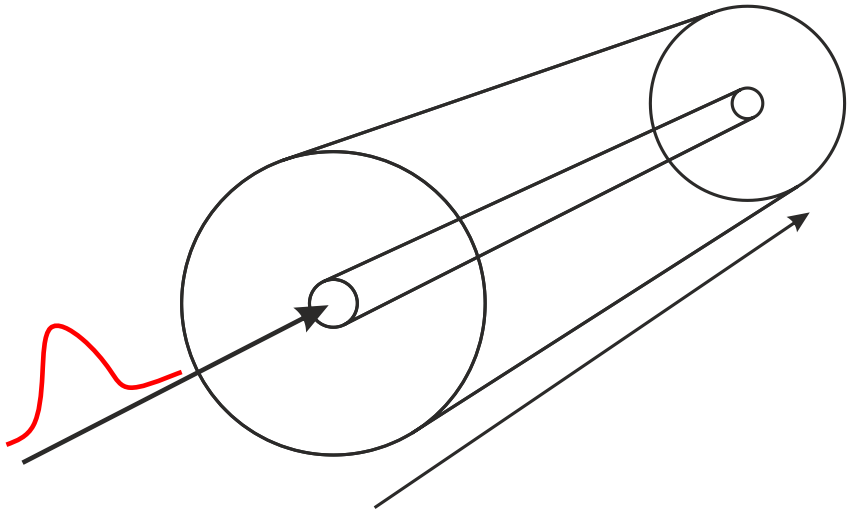
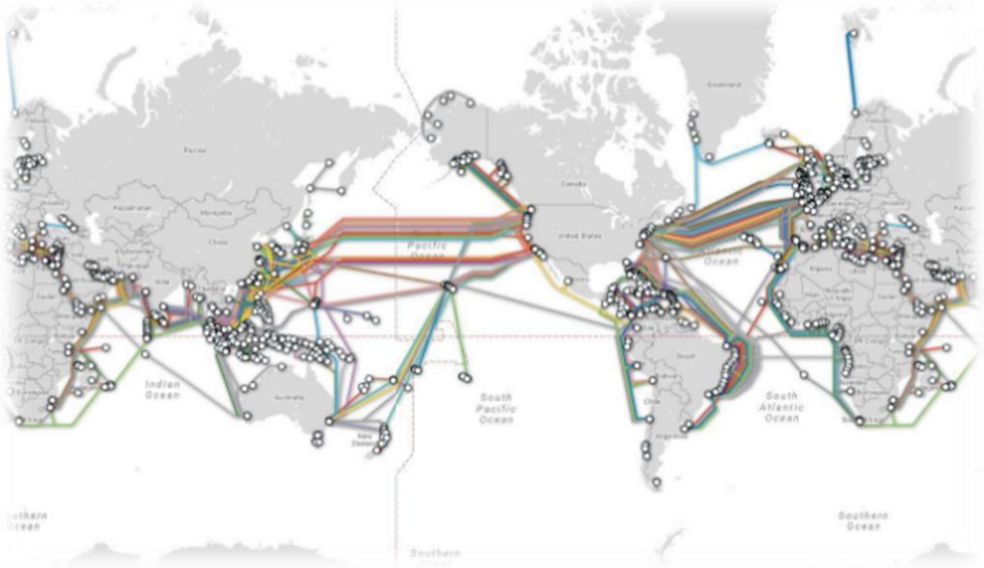
Optical Fibre





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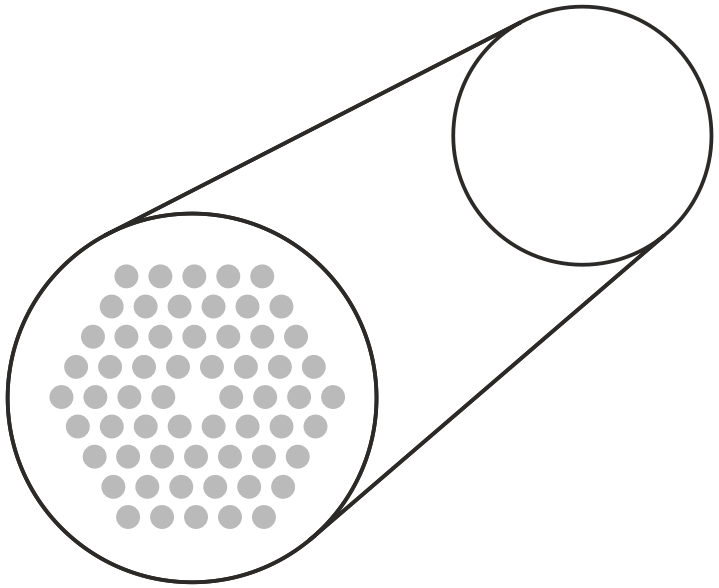

Air

Glass

Roberts et al., *Sci. Adv.* **8** (2022),
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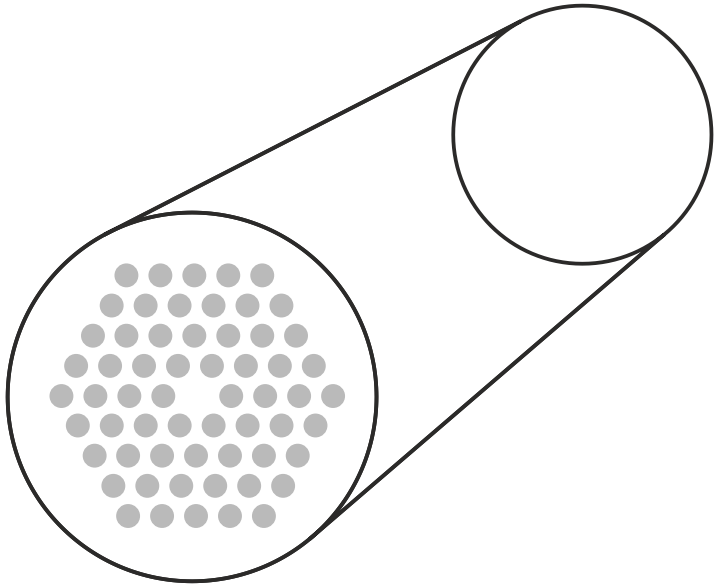
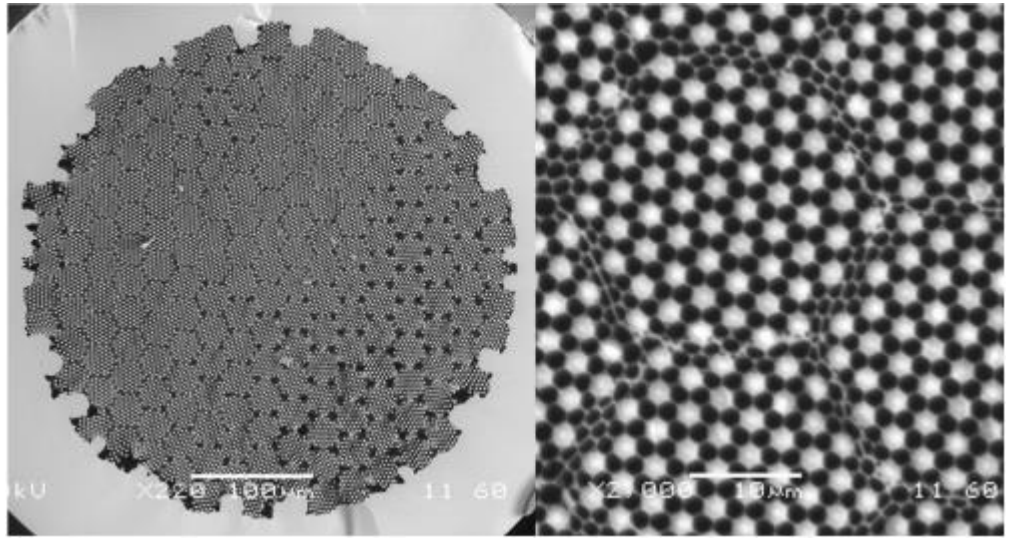
Optical Fibre

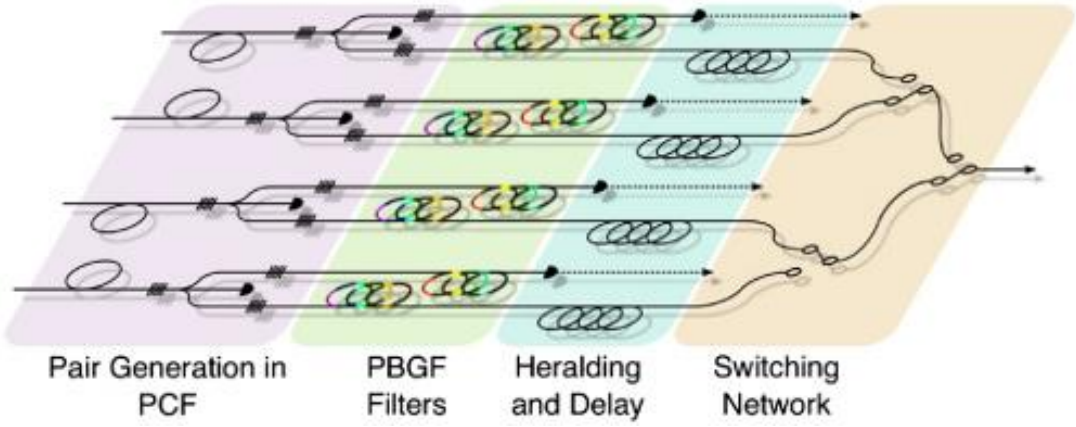


Air

Glass



H A C Wood et al., High-resolution air-clad imaging fibers
Opt. Lett. **43** 2018



Robert J. A. Francis-Jones et al. 2016
All-fiber multiplexed source of high-purity single photons
Optica **3**

Roberts et al., *Sci. Adv.* 8 (2022),
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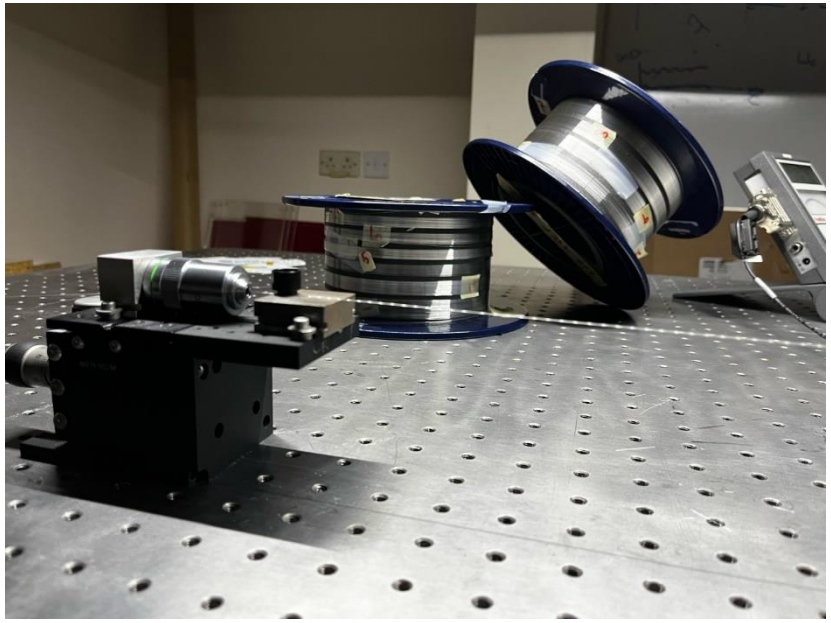

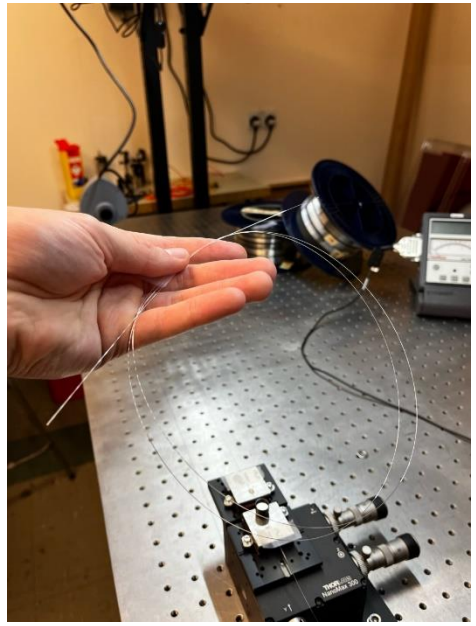

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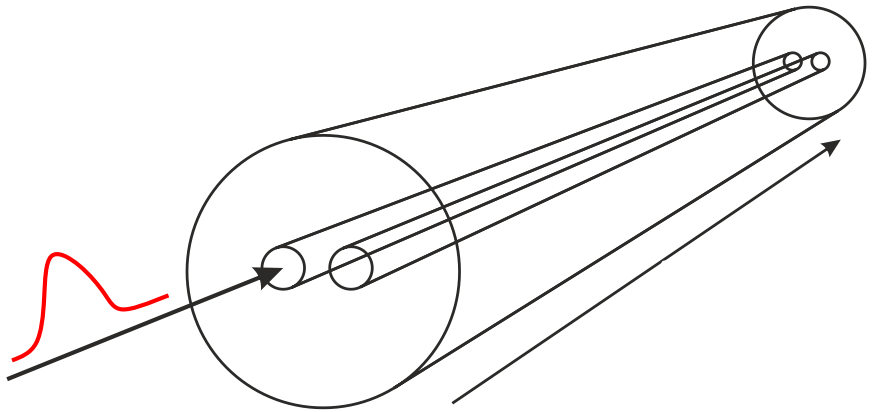
Light Propagation In Fibre



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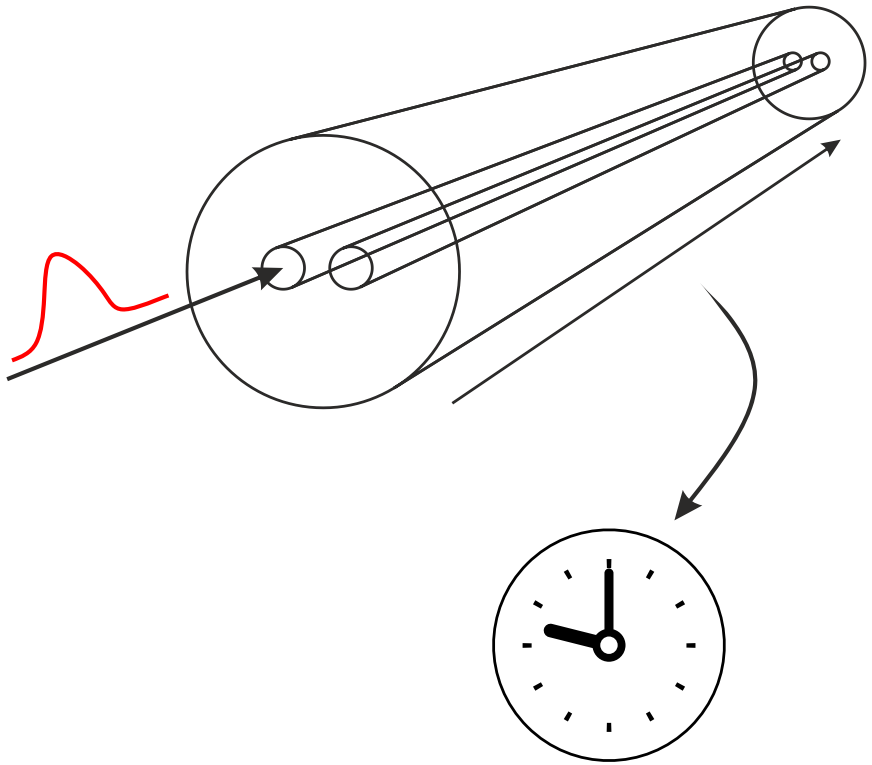

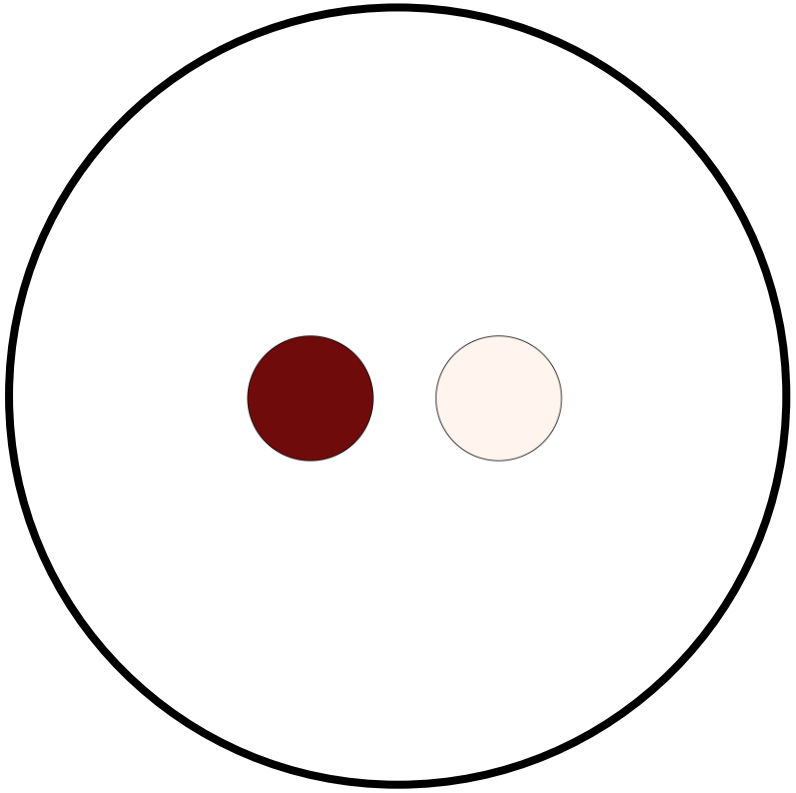

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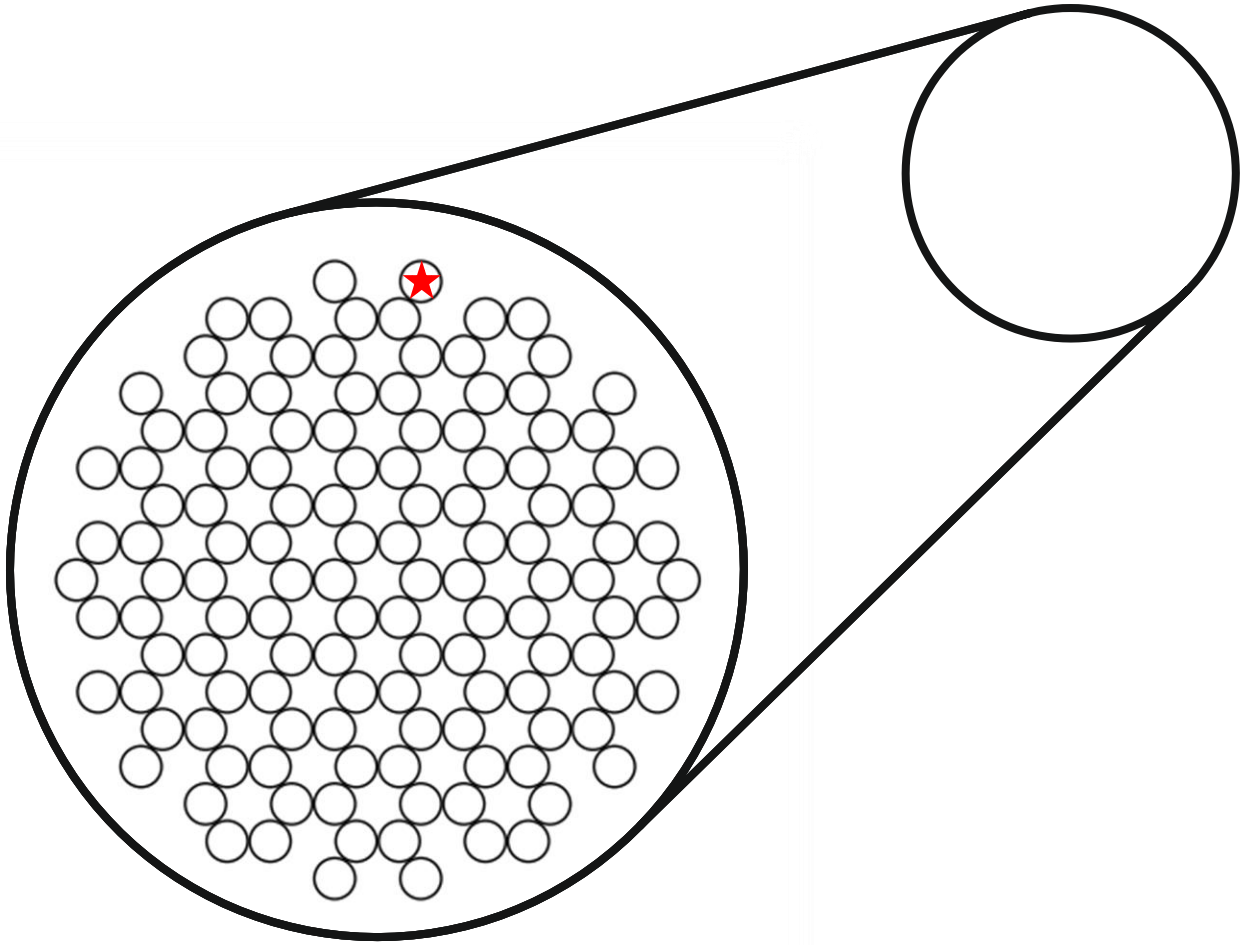

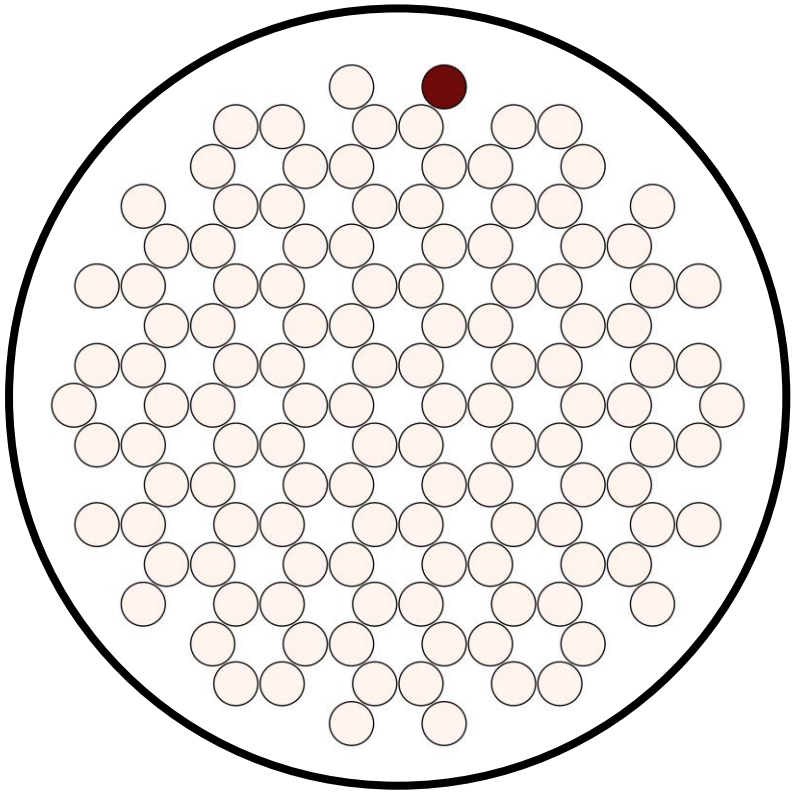

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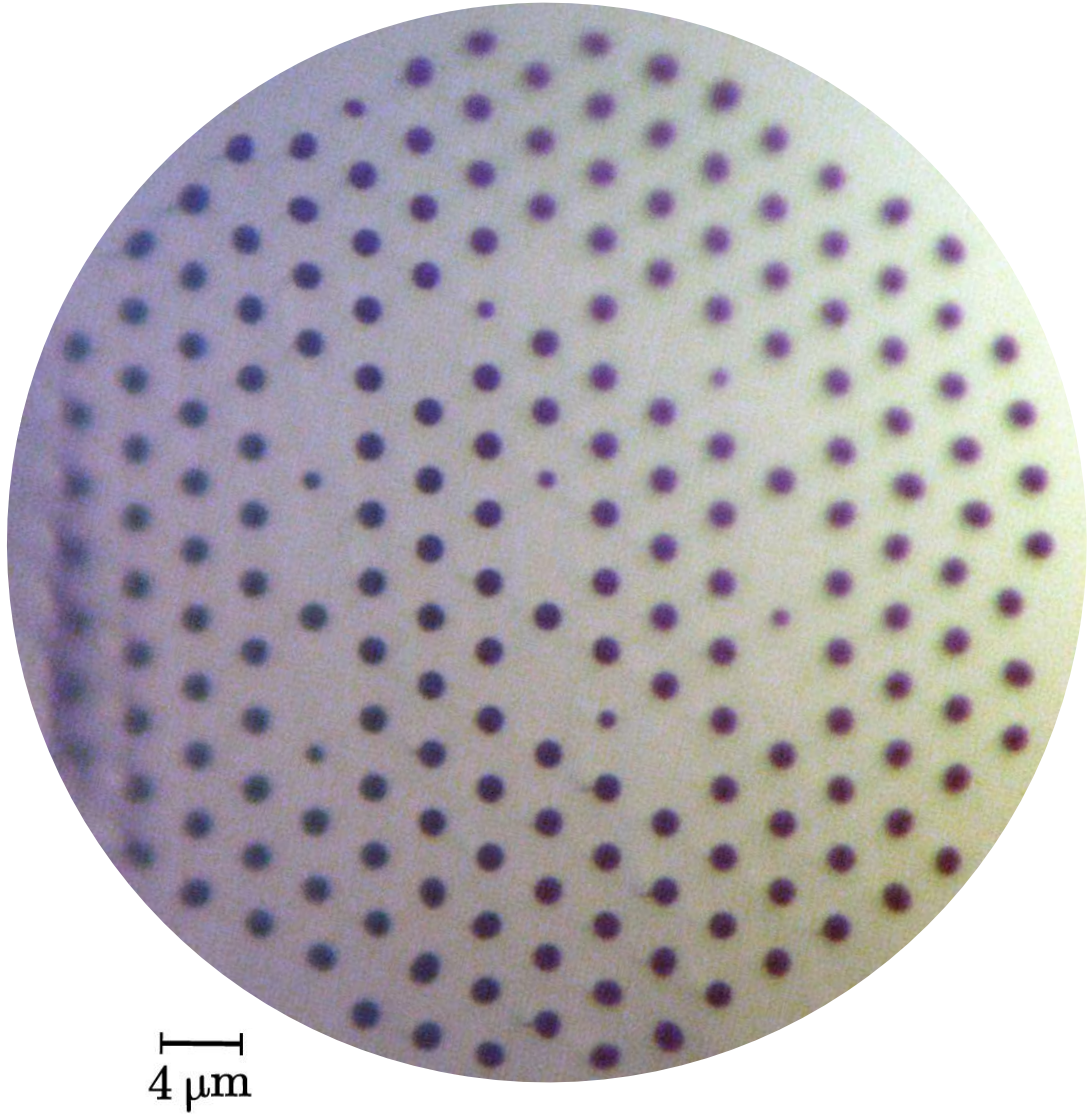

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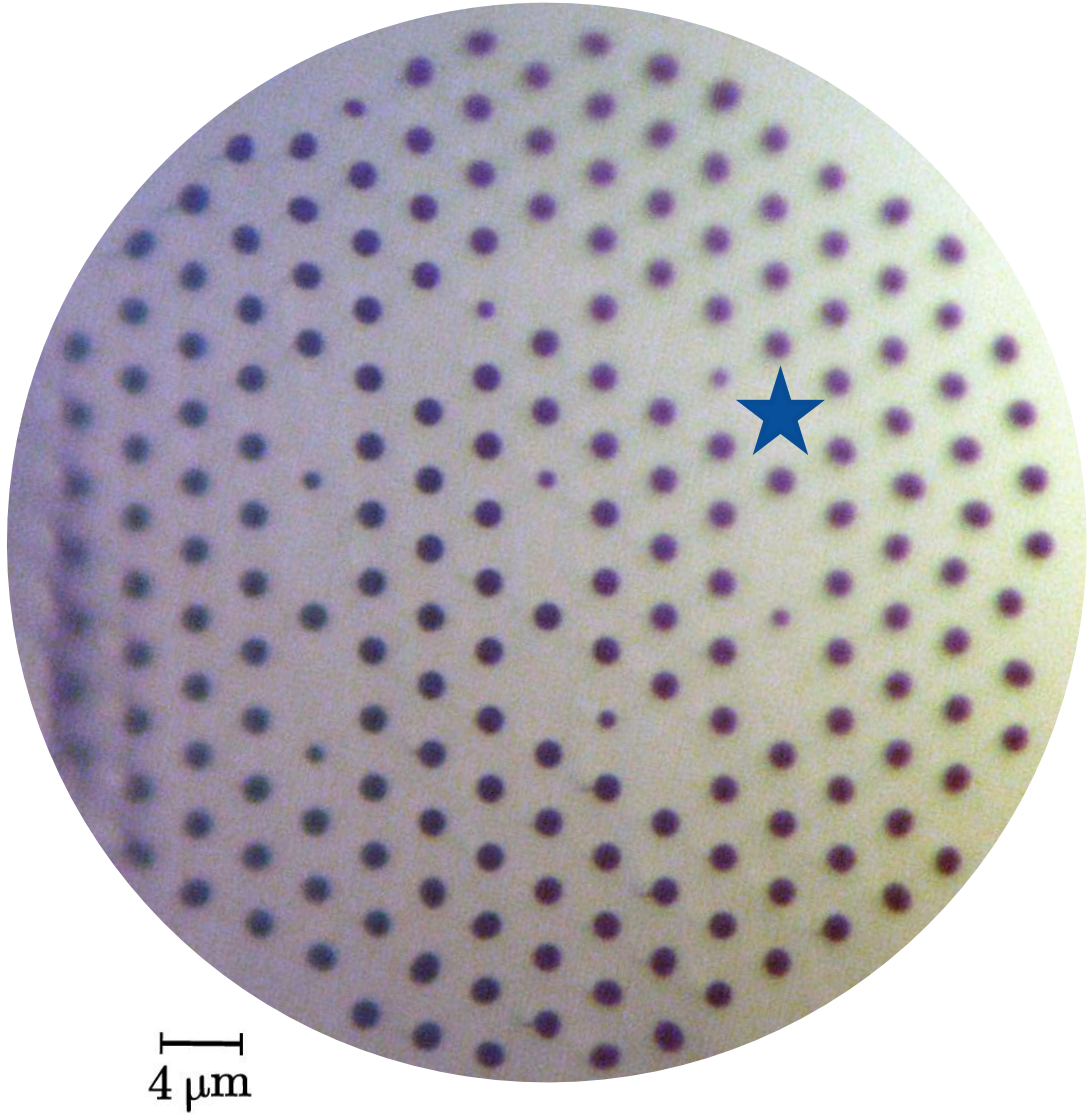

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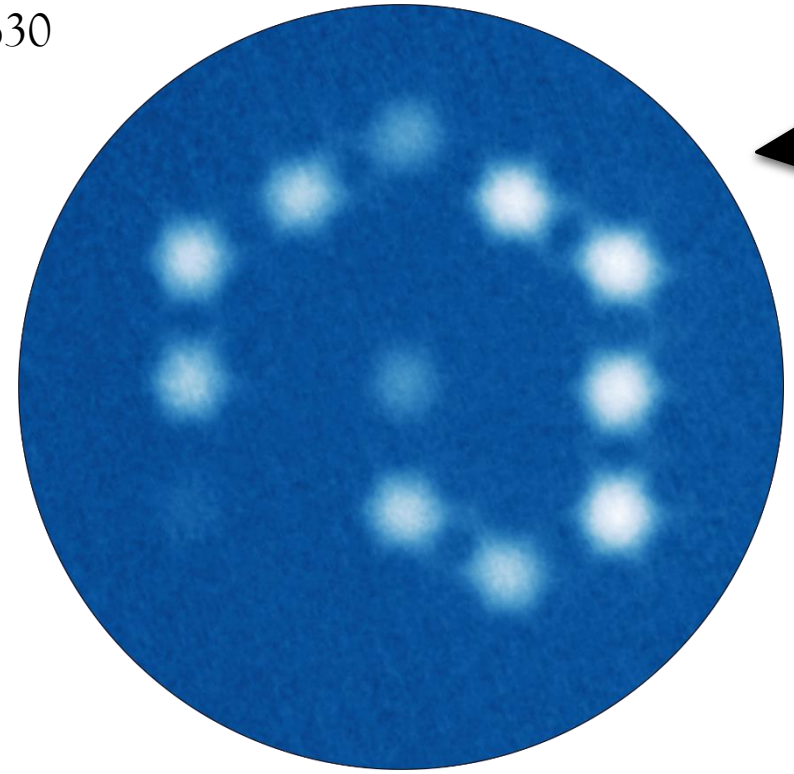
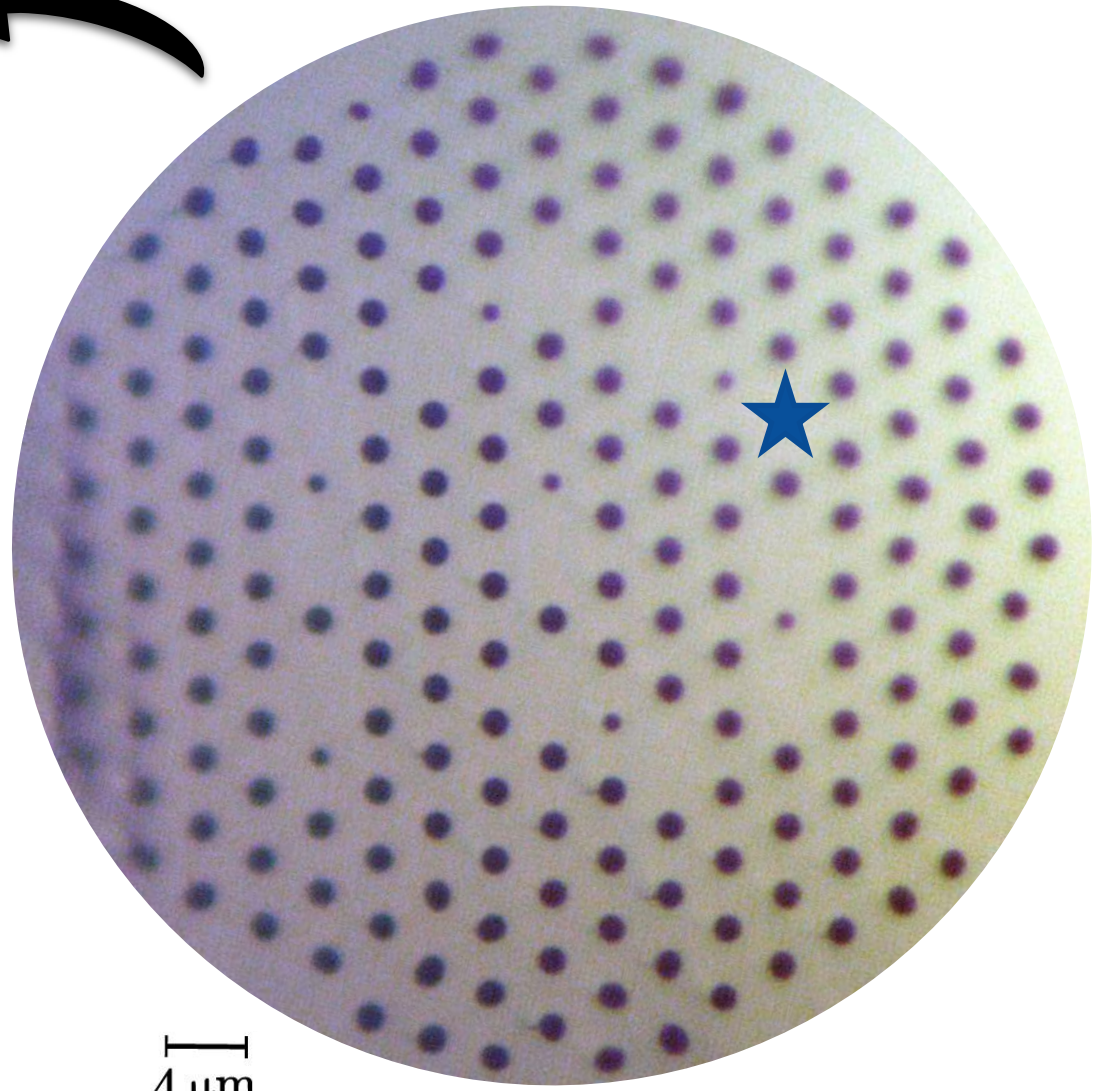


17cm



4 μm

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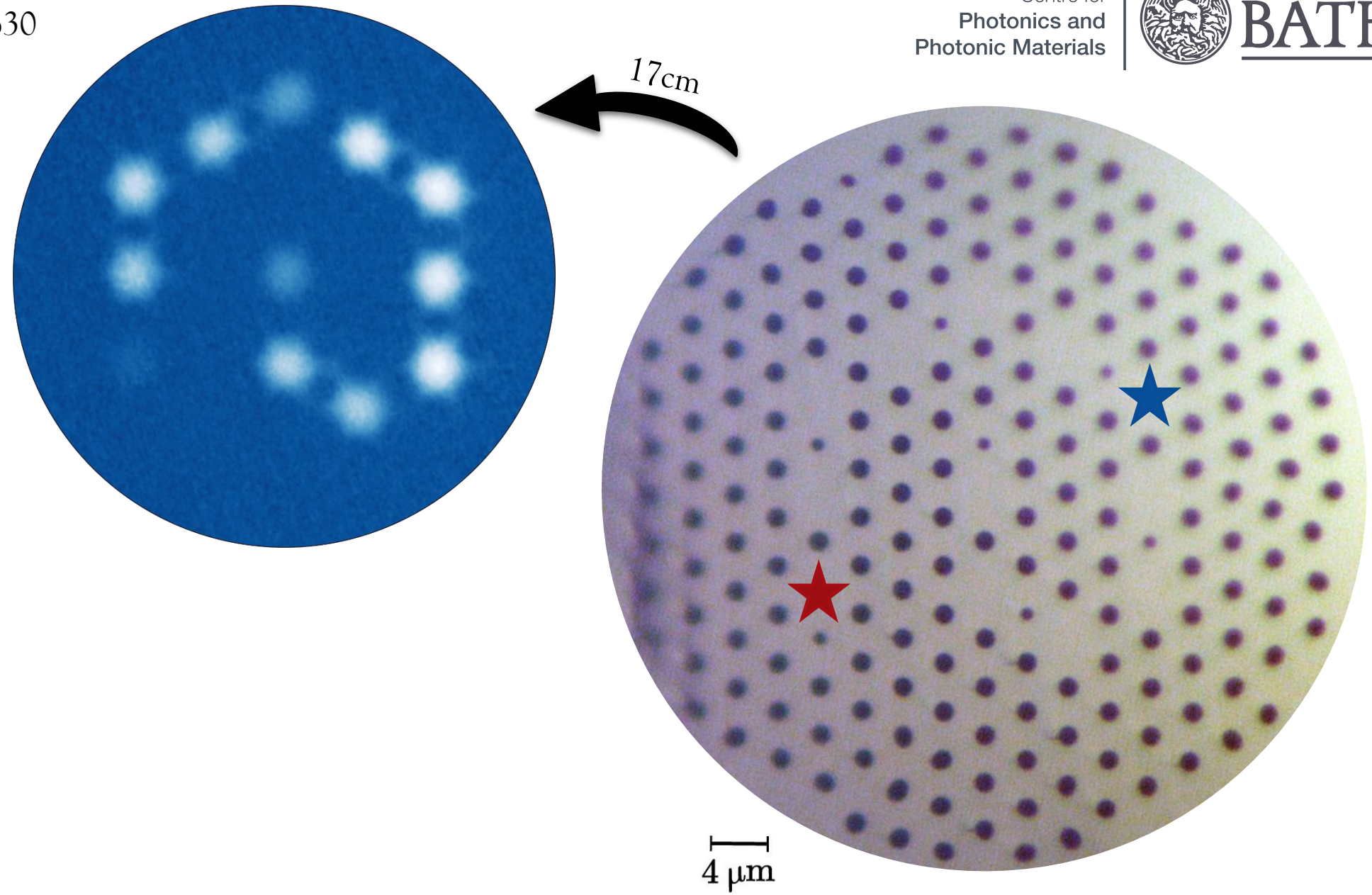

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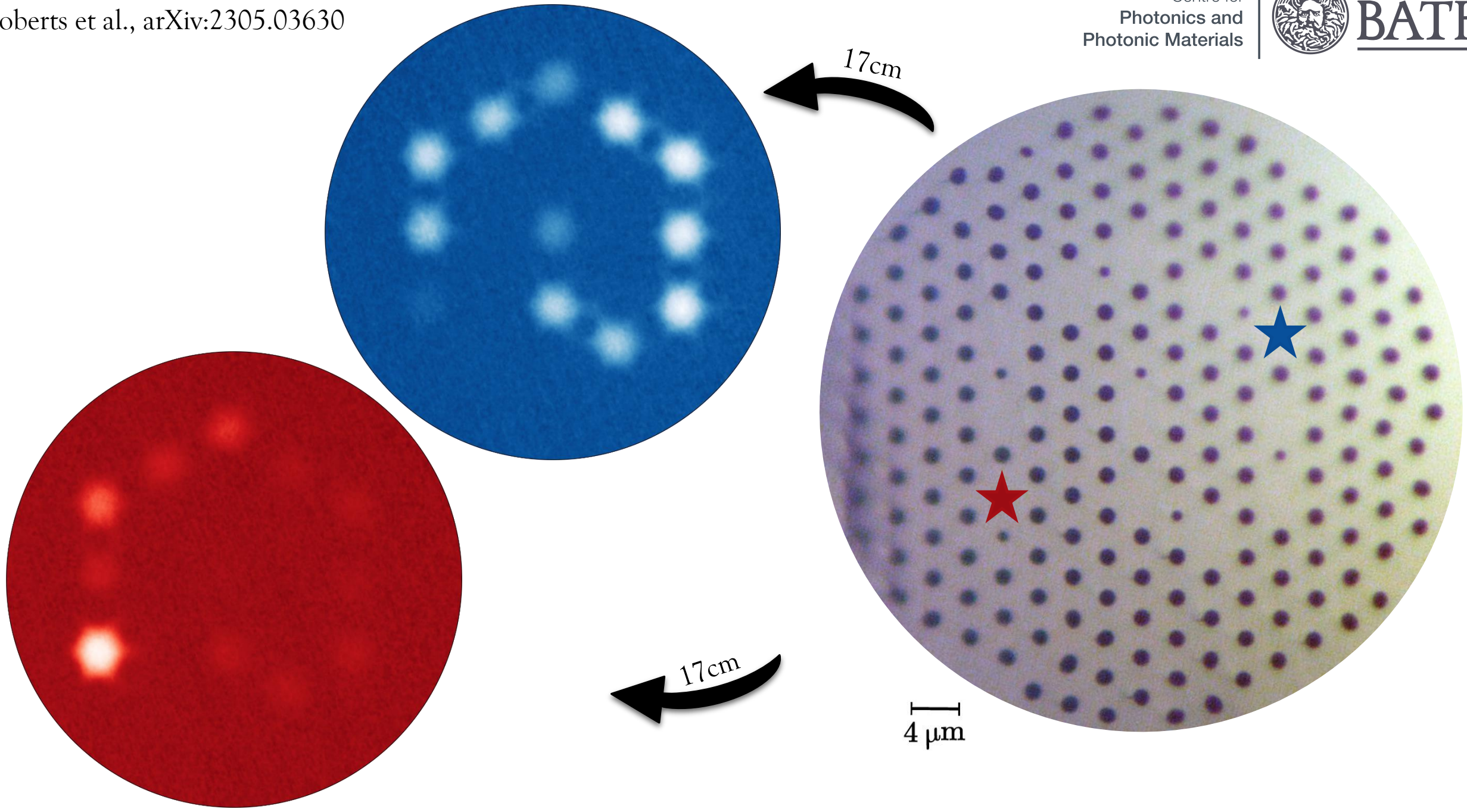

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What does it have to do with topological physics?

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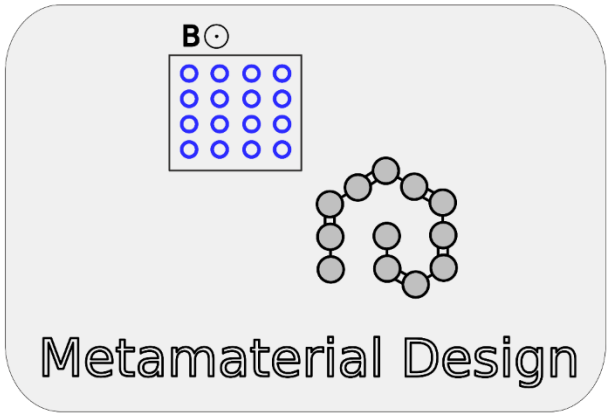

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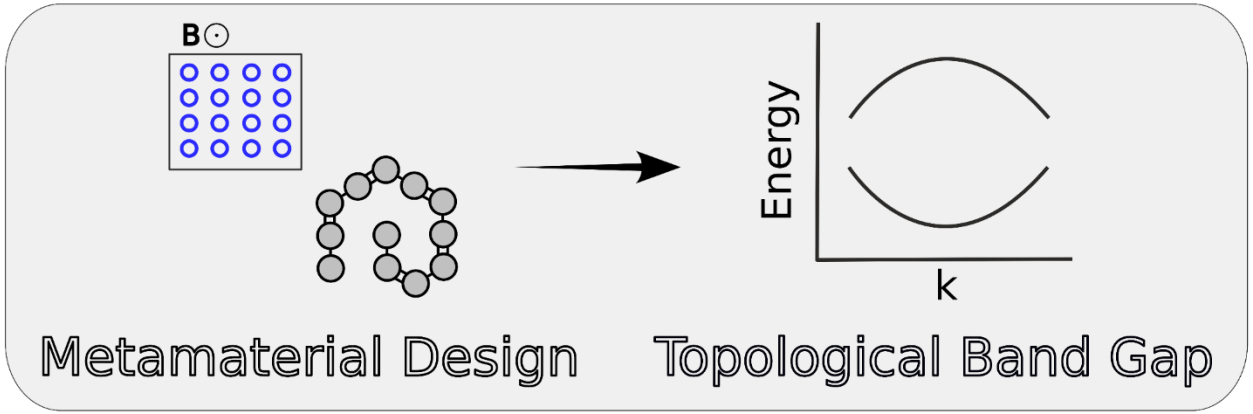
Topological Physics



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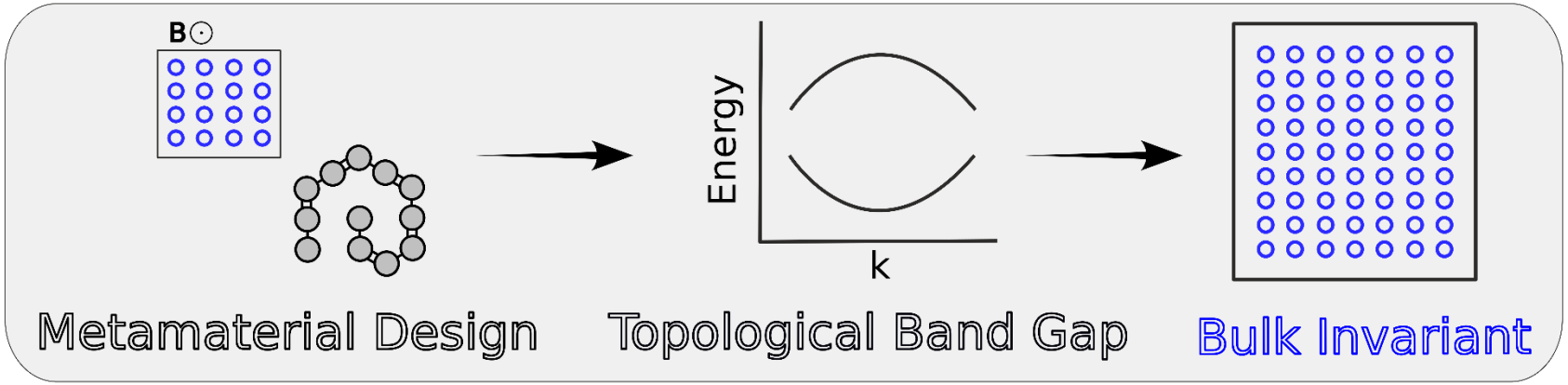

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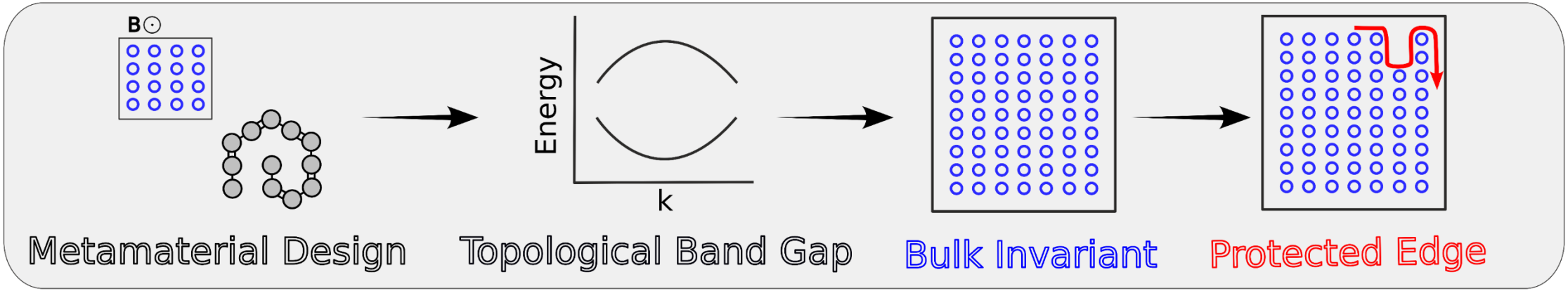

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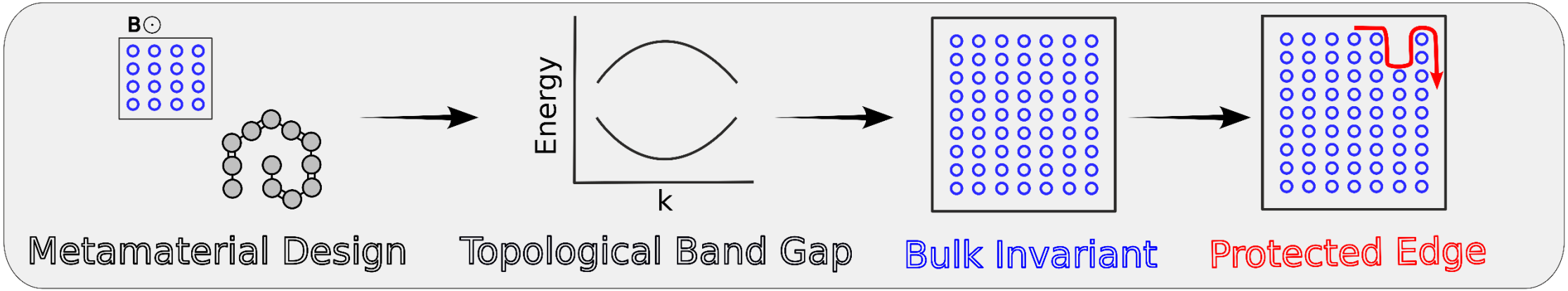
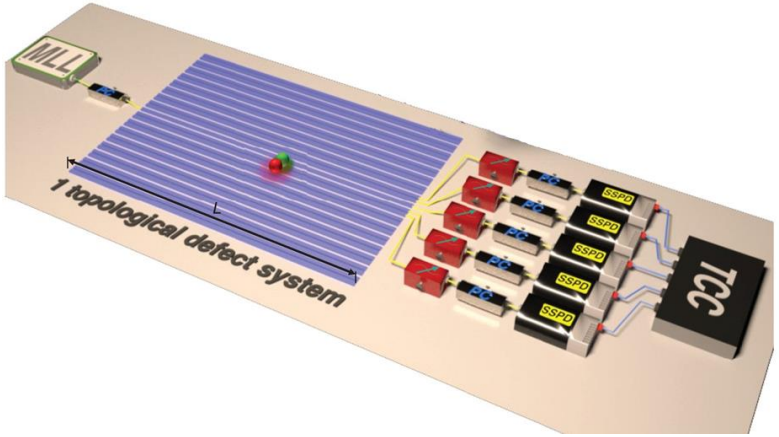
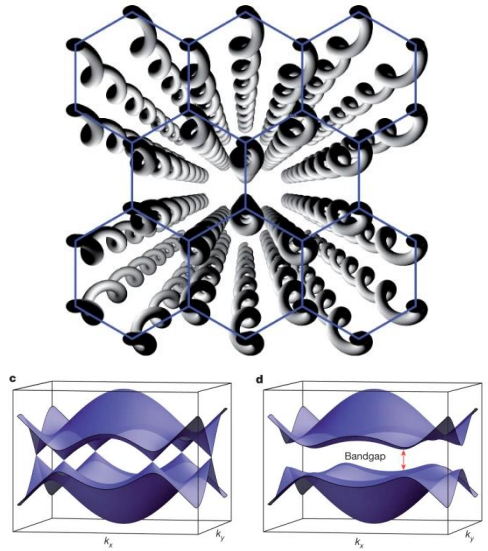
Topological Physics



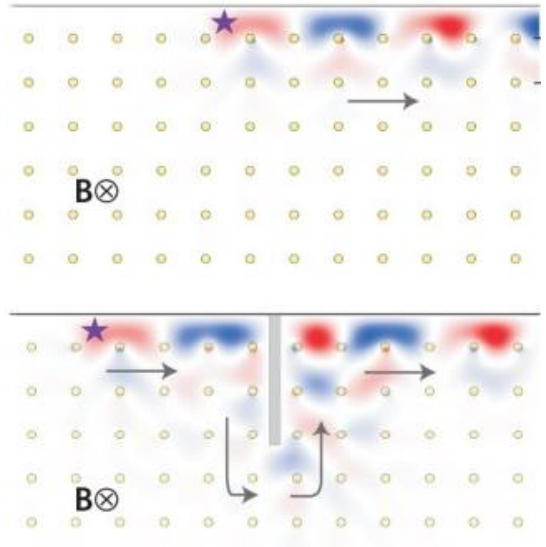
Topological Photonics



A Blanco-Redondo et al. *Science* **362** 2018



Rechtsman, M. et al. *Nature* **496**



Z Wang et al. *Nature* **461** 2009

Roberts et al., *Sci. Adv.* **8** (2022),
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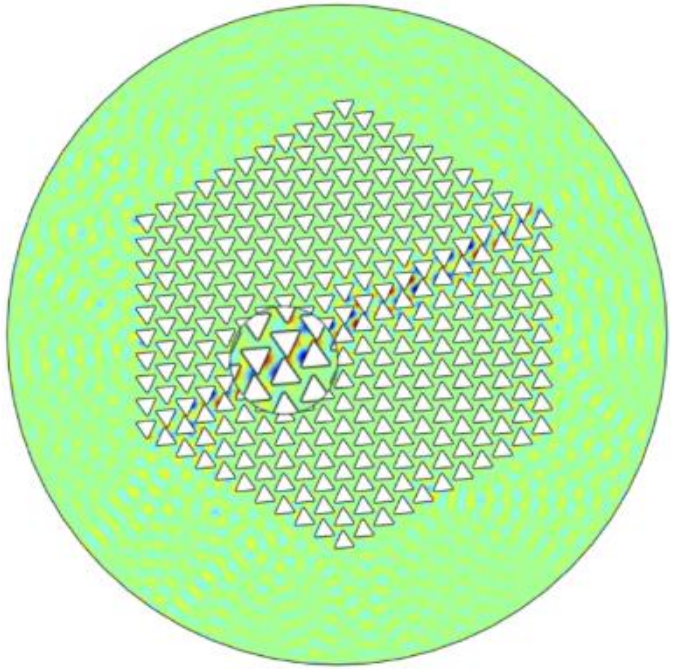
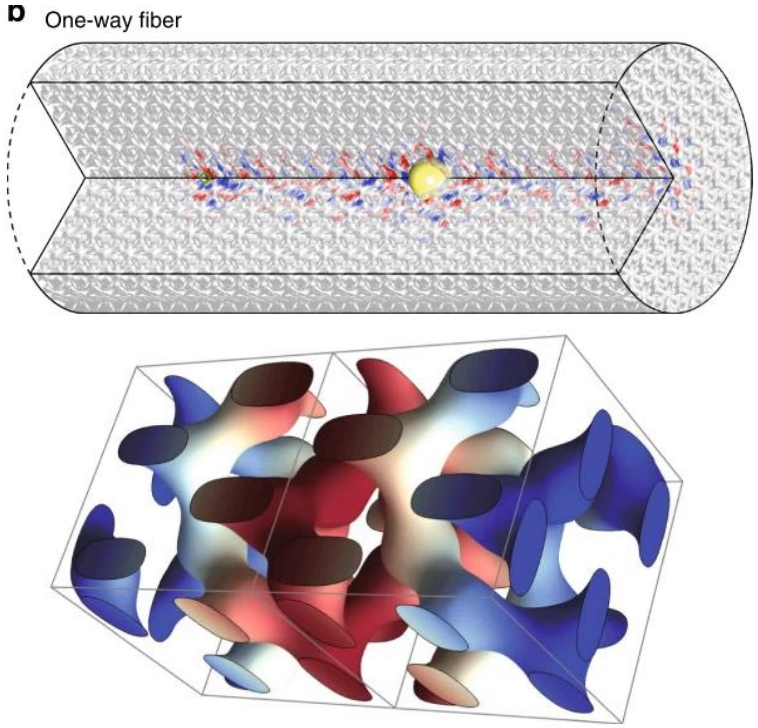


M Makwana et al.
Optics Express **461** 2020



Lu L et al.
Nat. Commun. **9** 2018

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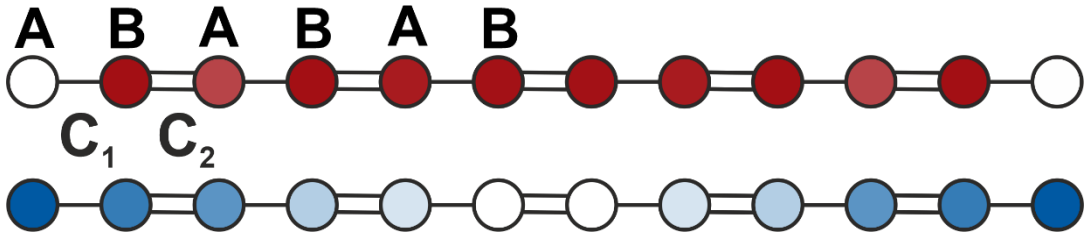
Design and Implementation



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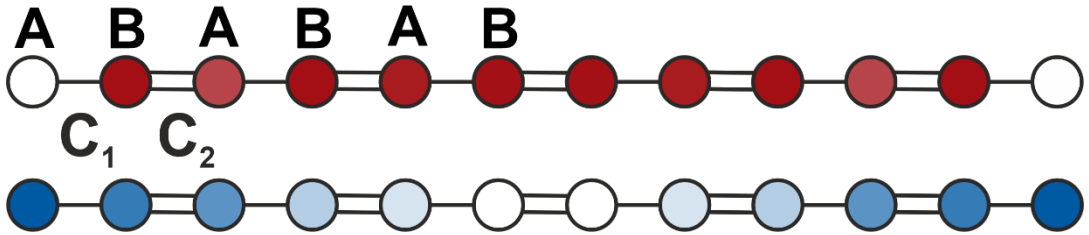

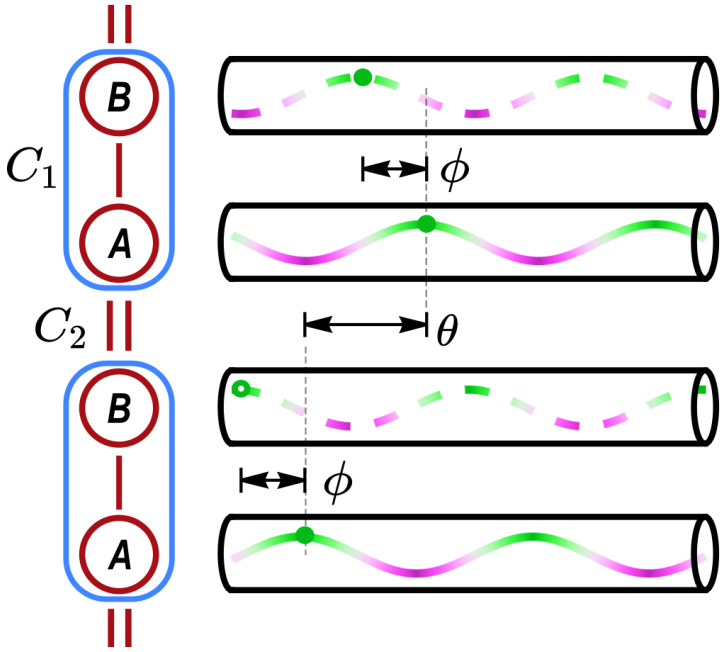

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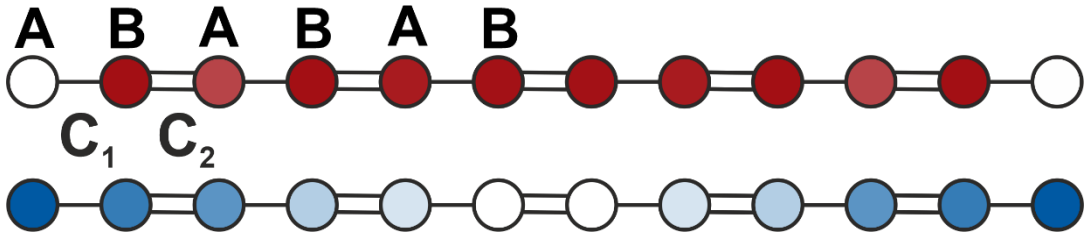

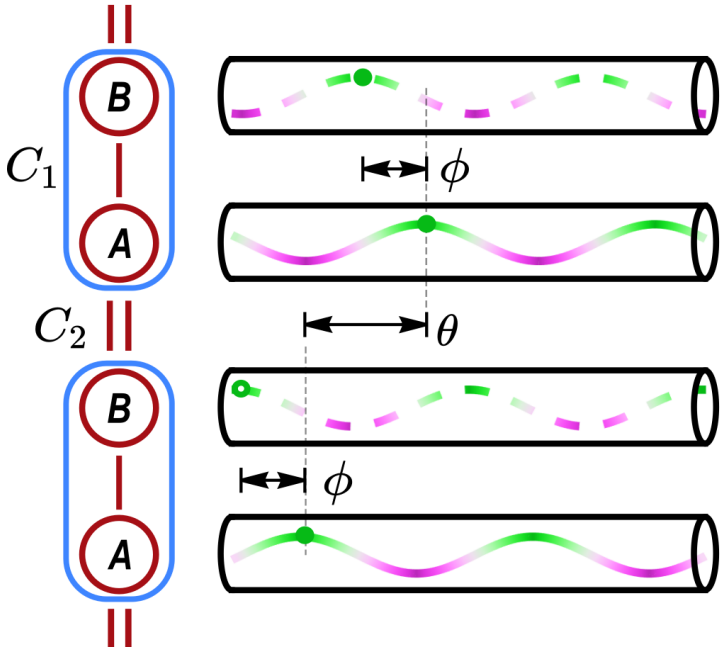

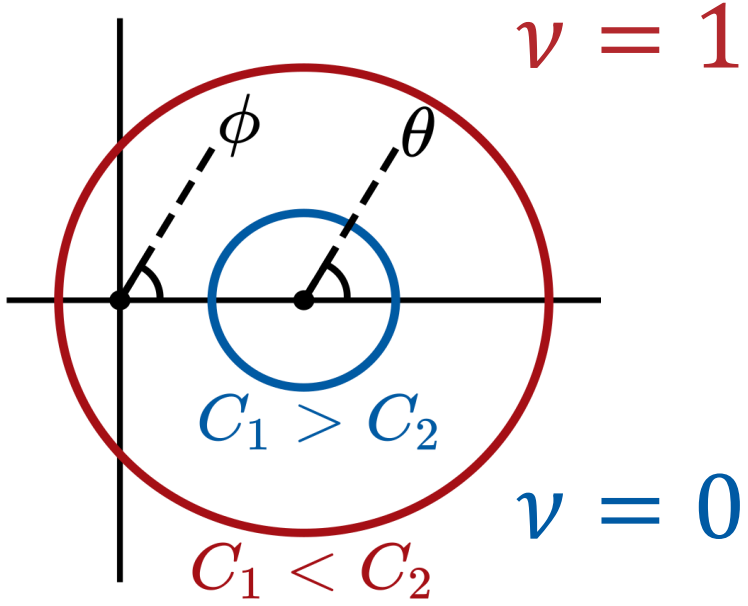

$\nu = 1$

$\nu = 0$

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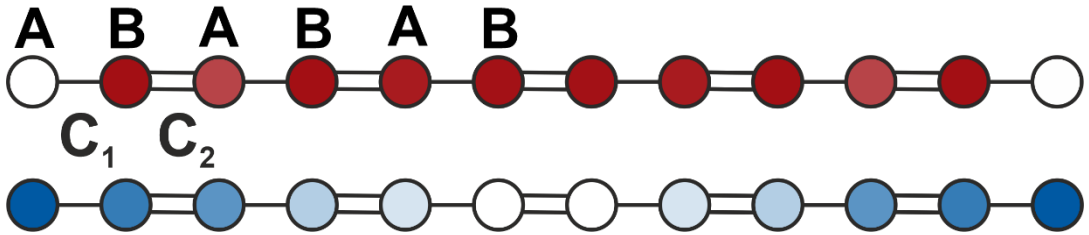

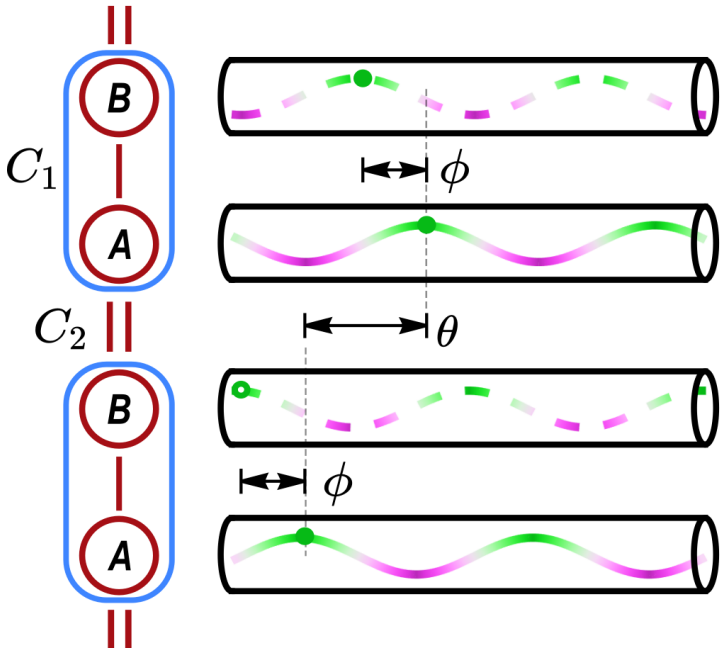

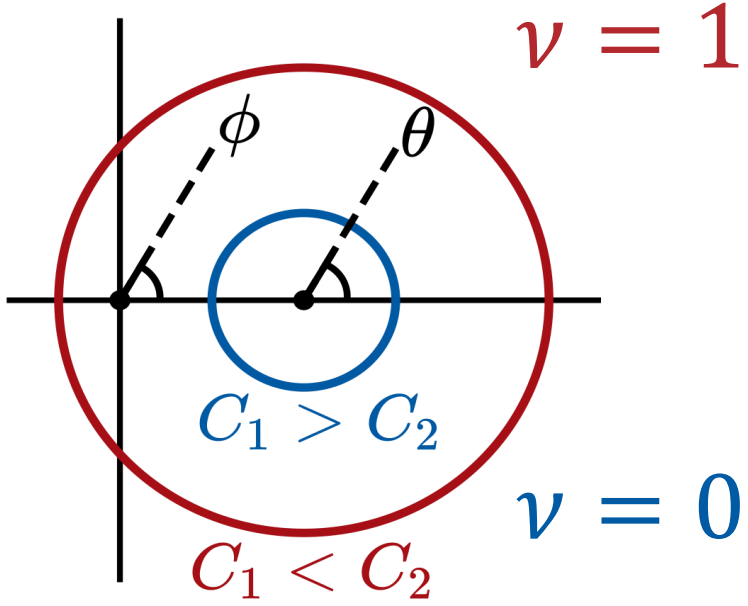

$\nu = 1$

$\nu = 0$

$$\Delta\beta \boldsymbol{a} = C_{ssh}\boldsymbol{a}$$

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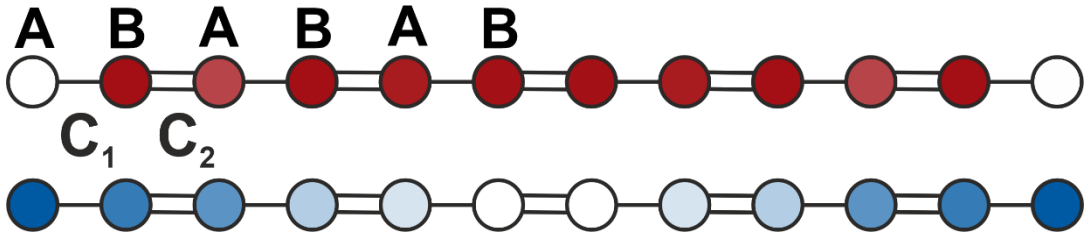

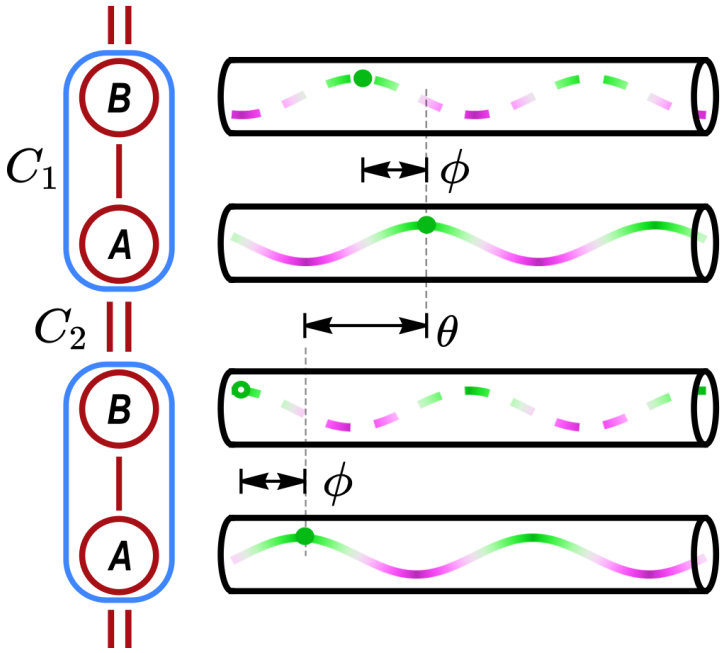

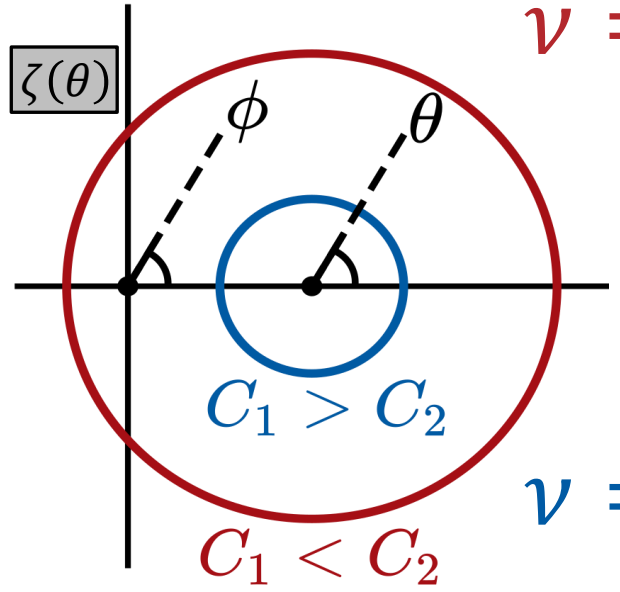

$\nu = 1$

$\nu = 0$

$$\Delta\beta \boldsymbol{a} = C_{ssh}\boldsymbol{a}$$

$$\Delta\beta = \pm|\zeta(\theta)|$$

$$\boldsymbol{a}(\theta) = \frac{1}{\sqrt{2}}\begin{pmatrix} \pm e^{i\phi(\theta)} \\ 1 \end{pmatrix}$$

$$\zeta(\theta) = C_1 + C_2 e^{i\theta} = |\zeta(\theta)|e^{i\phi(\theta)}$$

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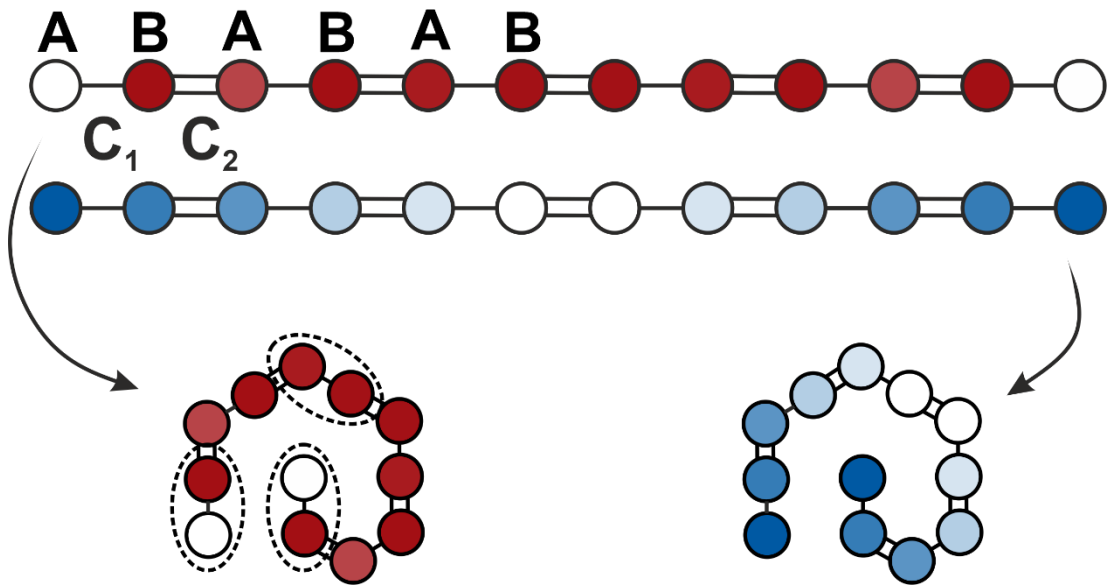

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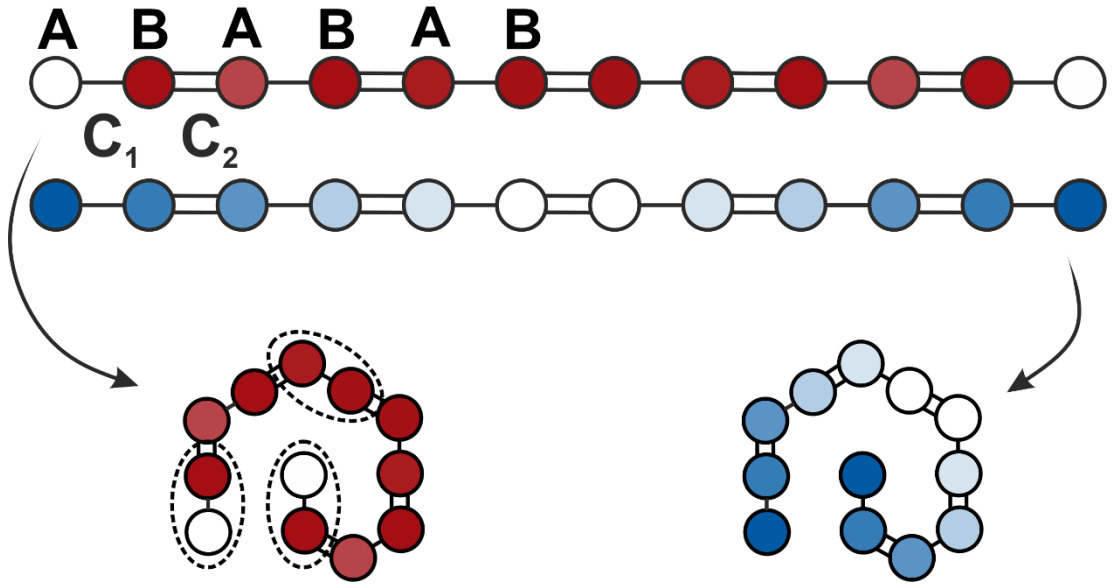

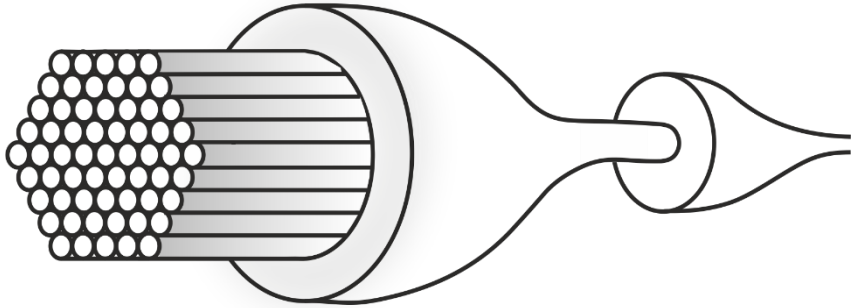

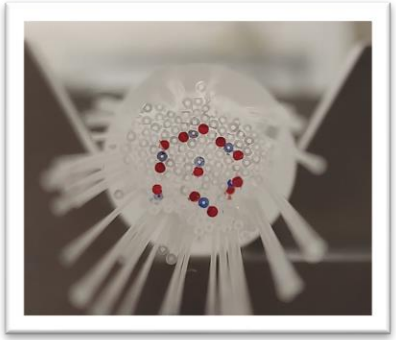

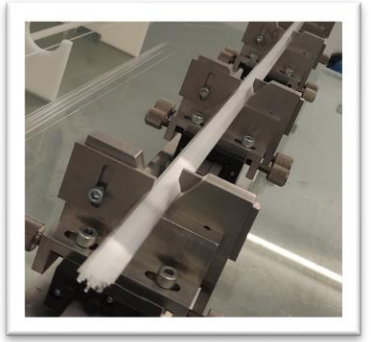

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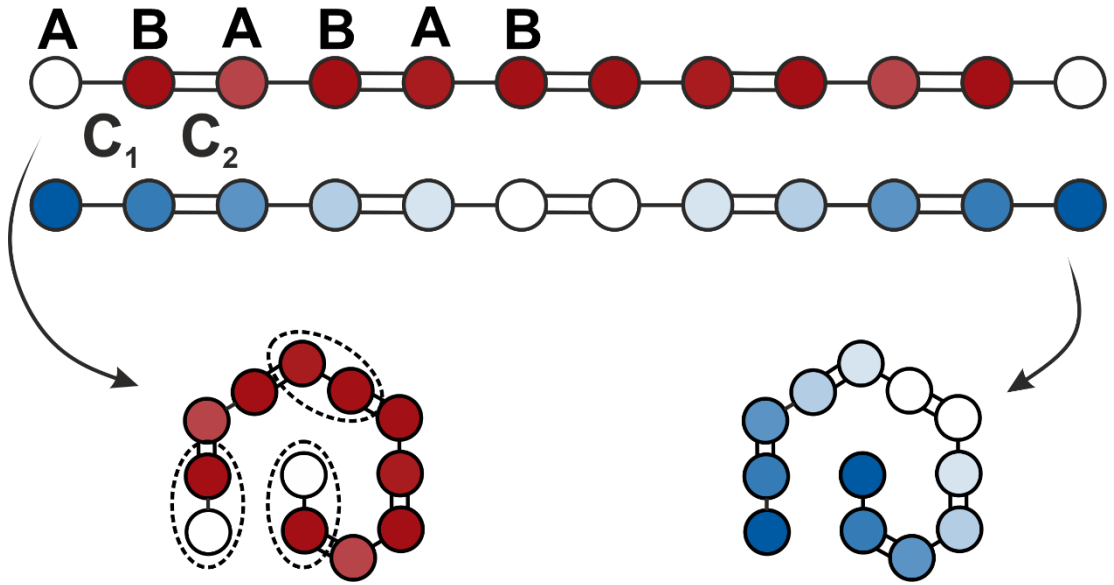
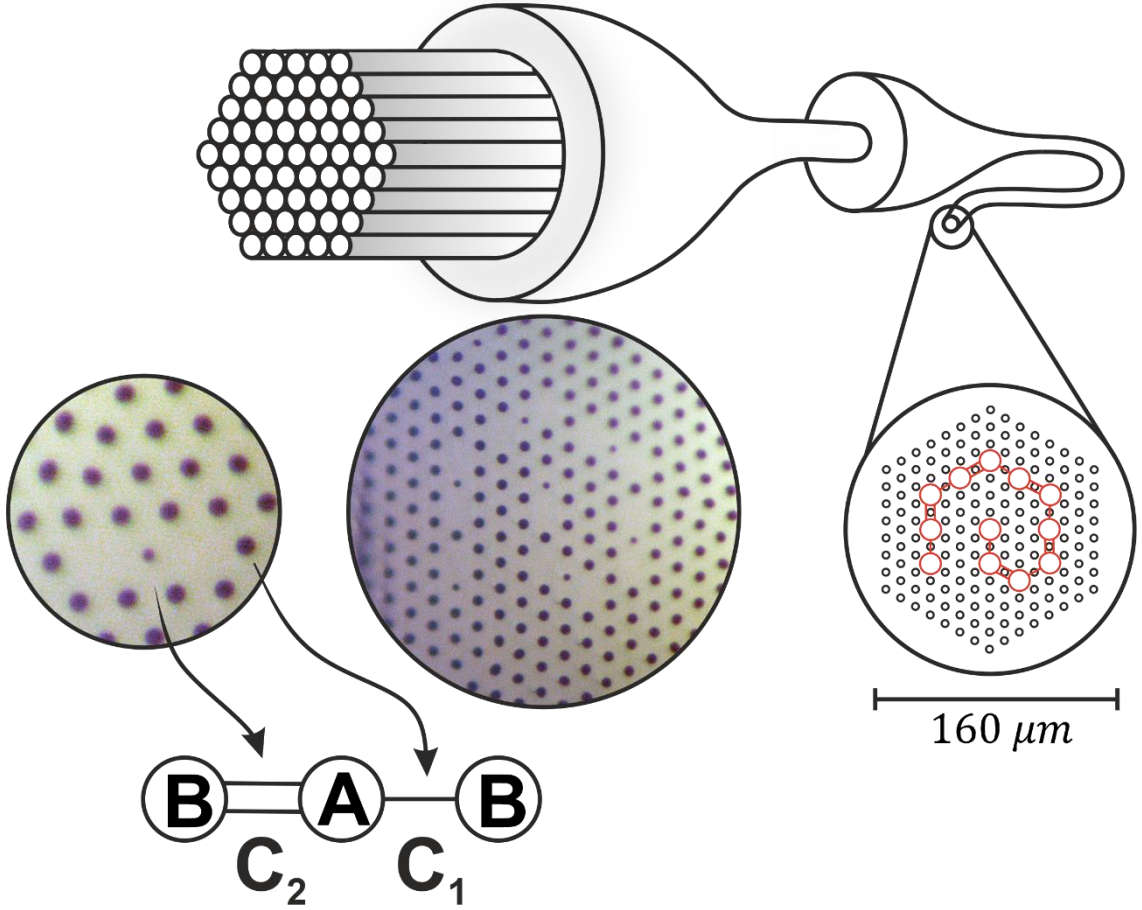
Design and Implementation





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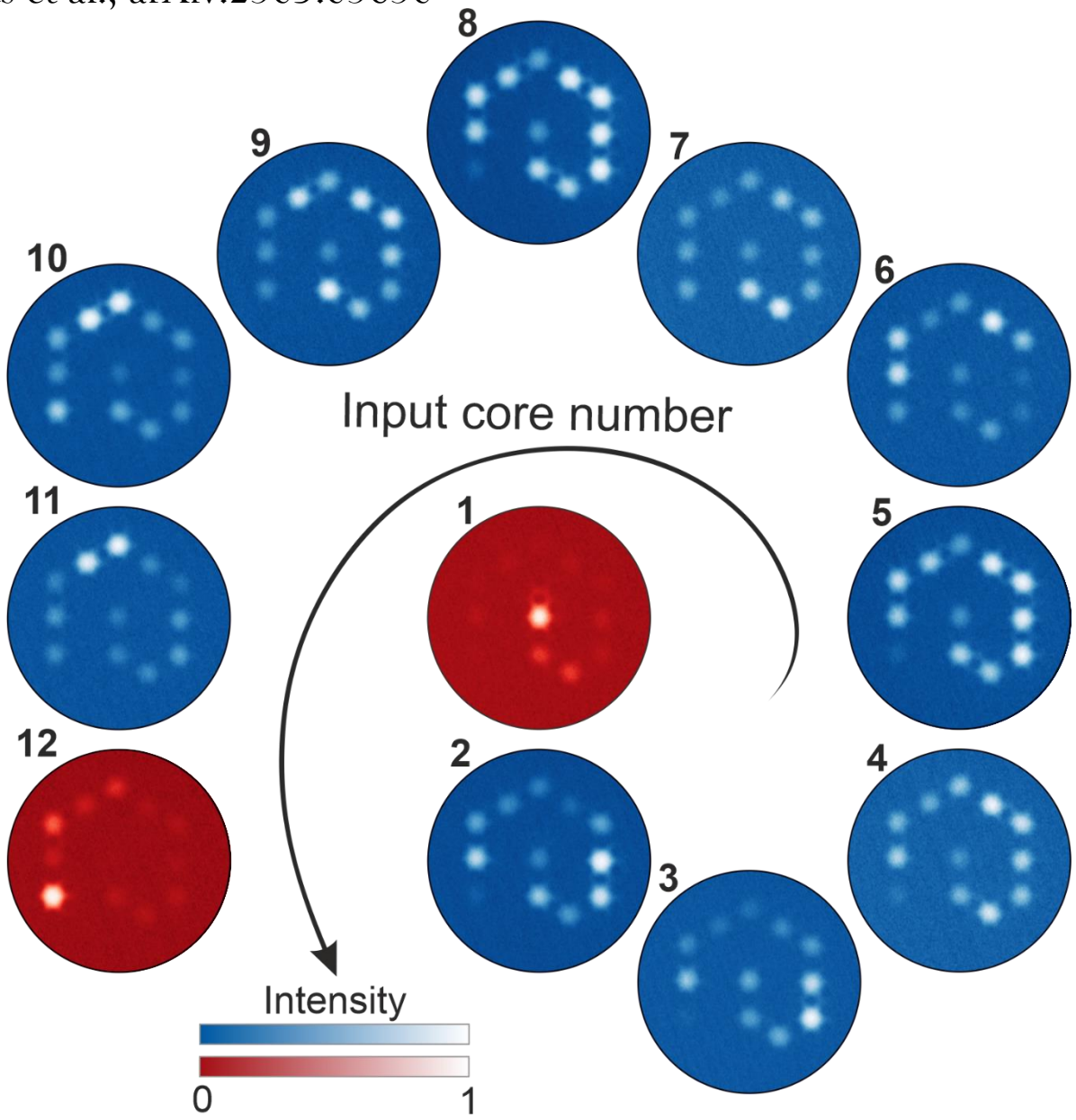

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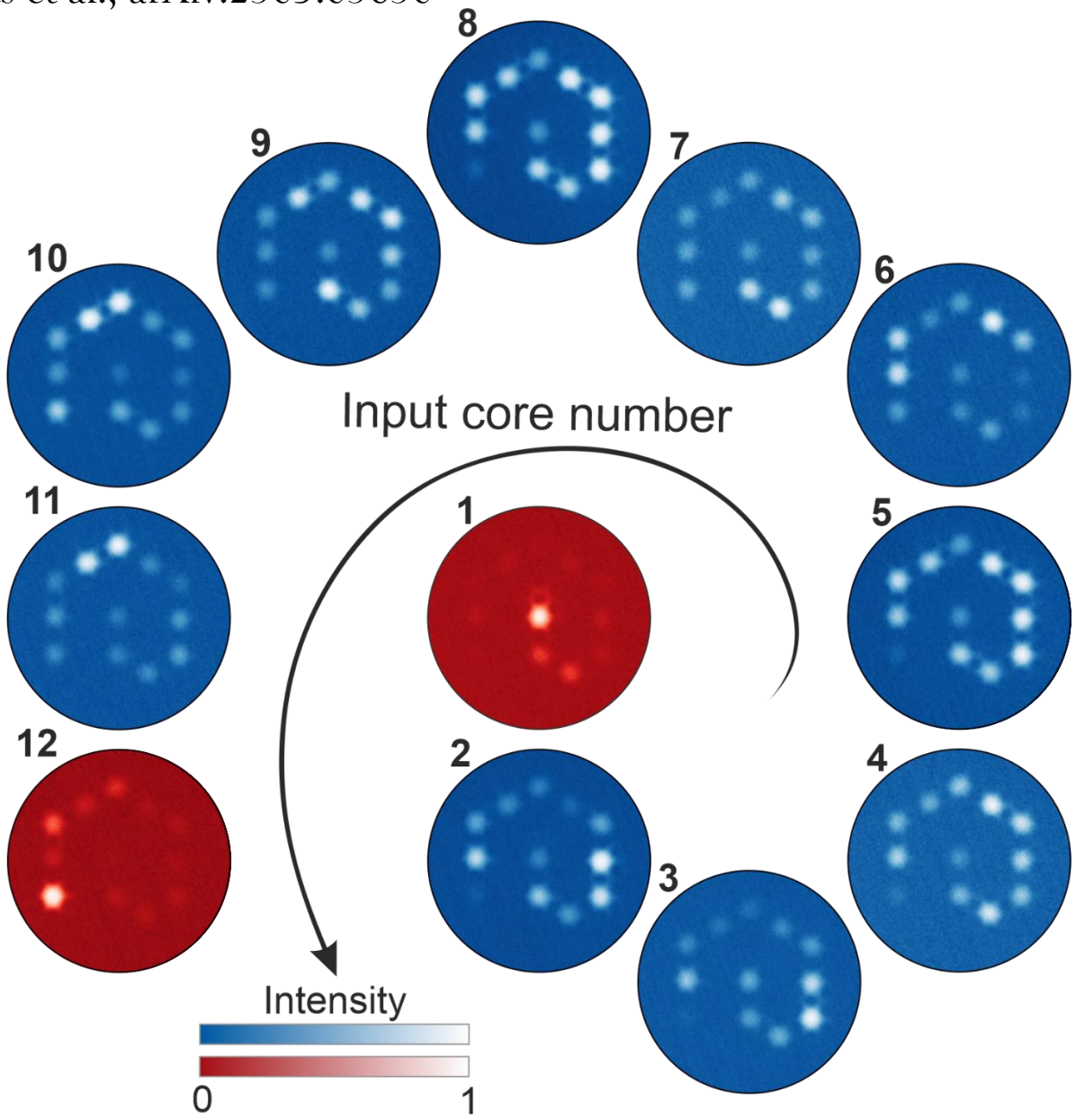

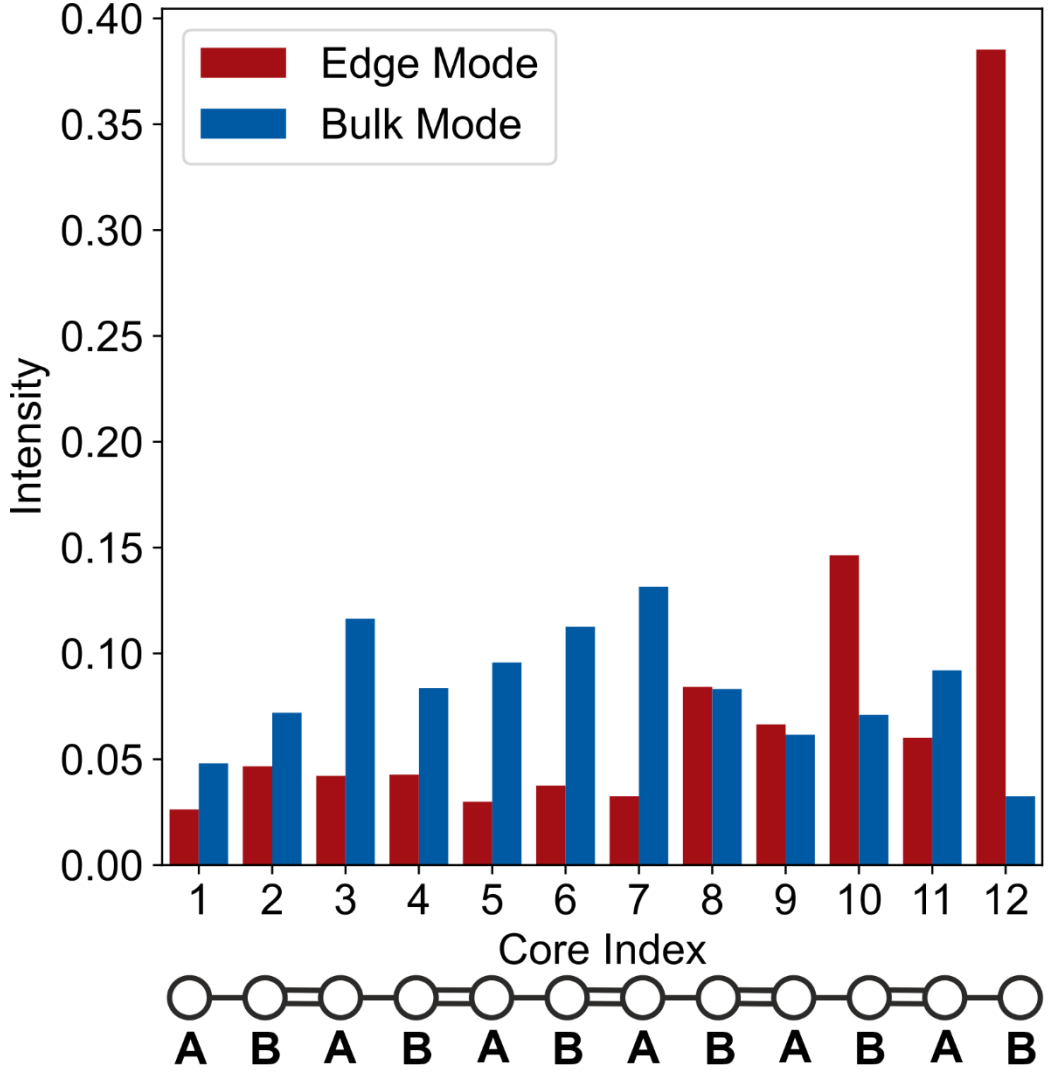

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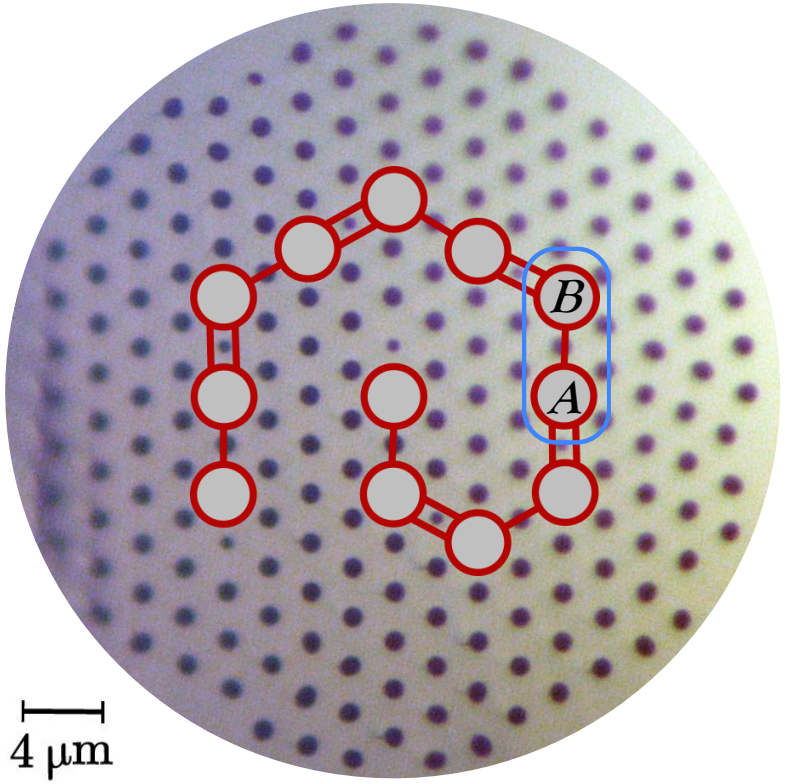
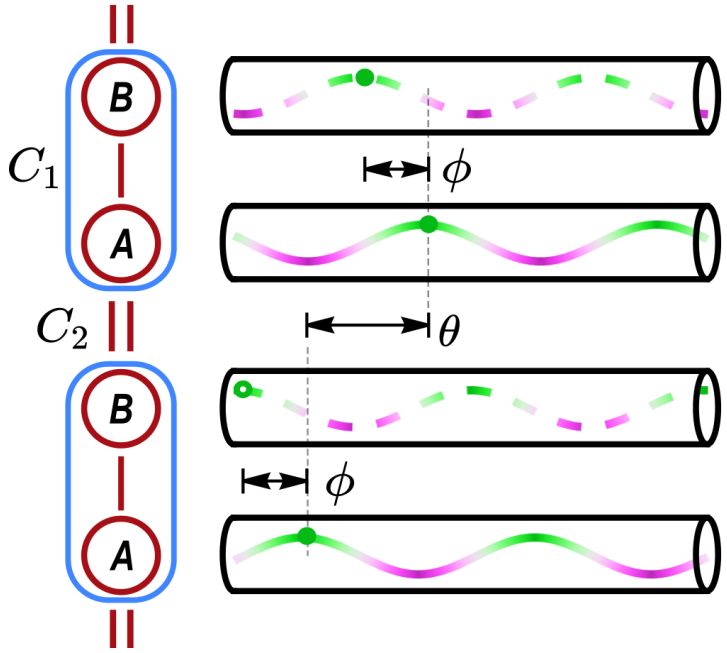
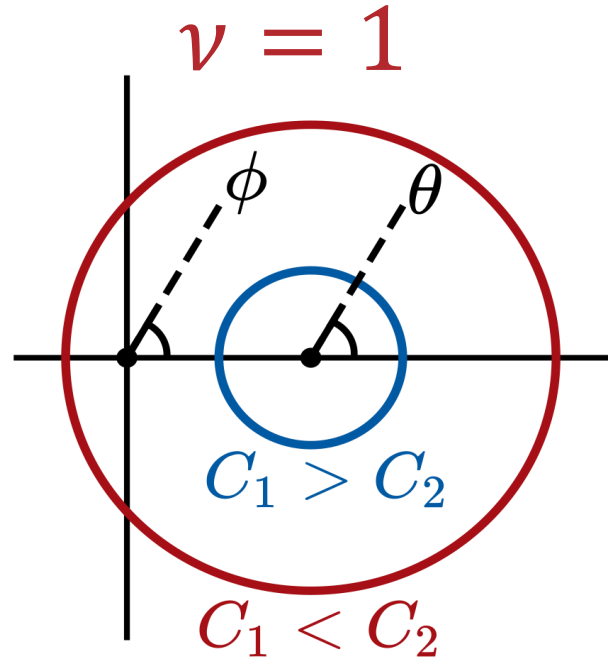
Invariant Calculation







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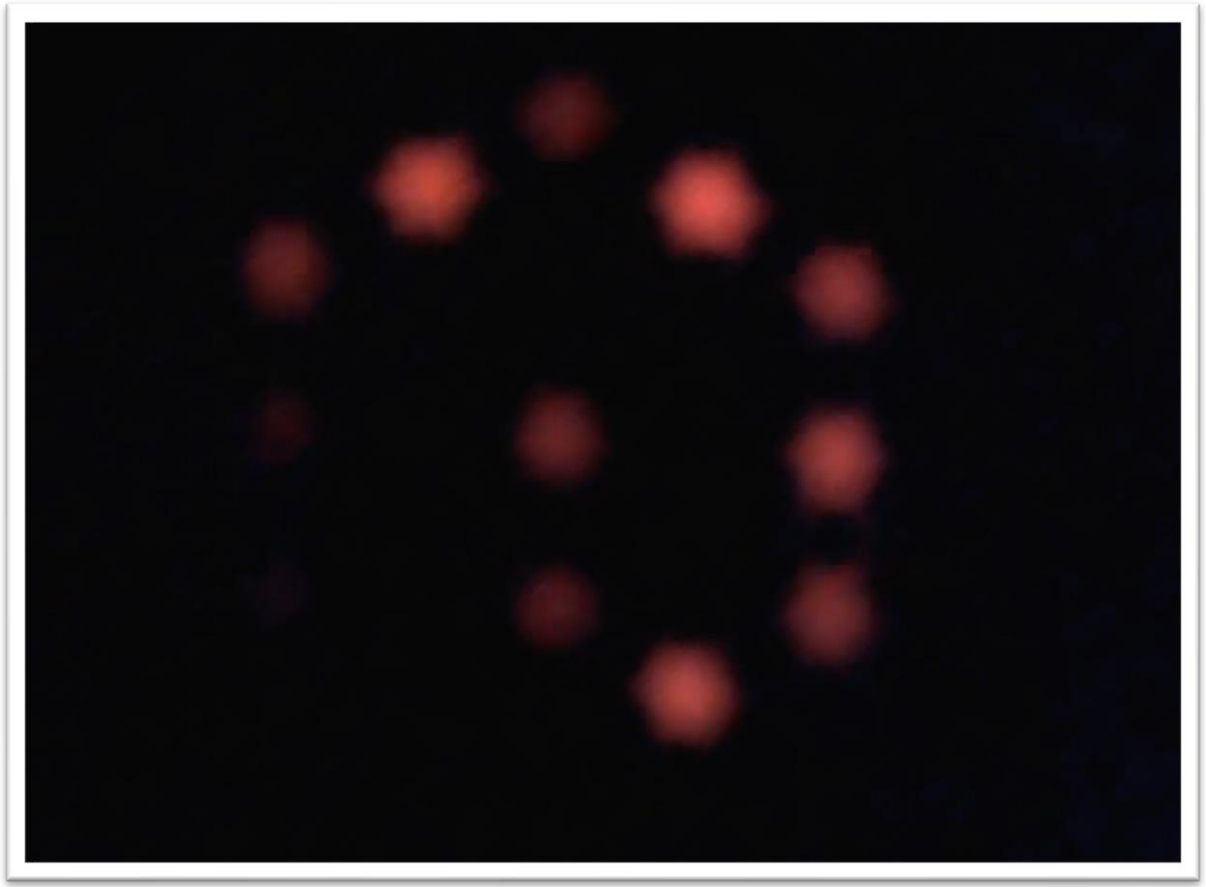

Varying input wavelength 600nm – 650 nm

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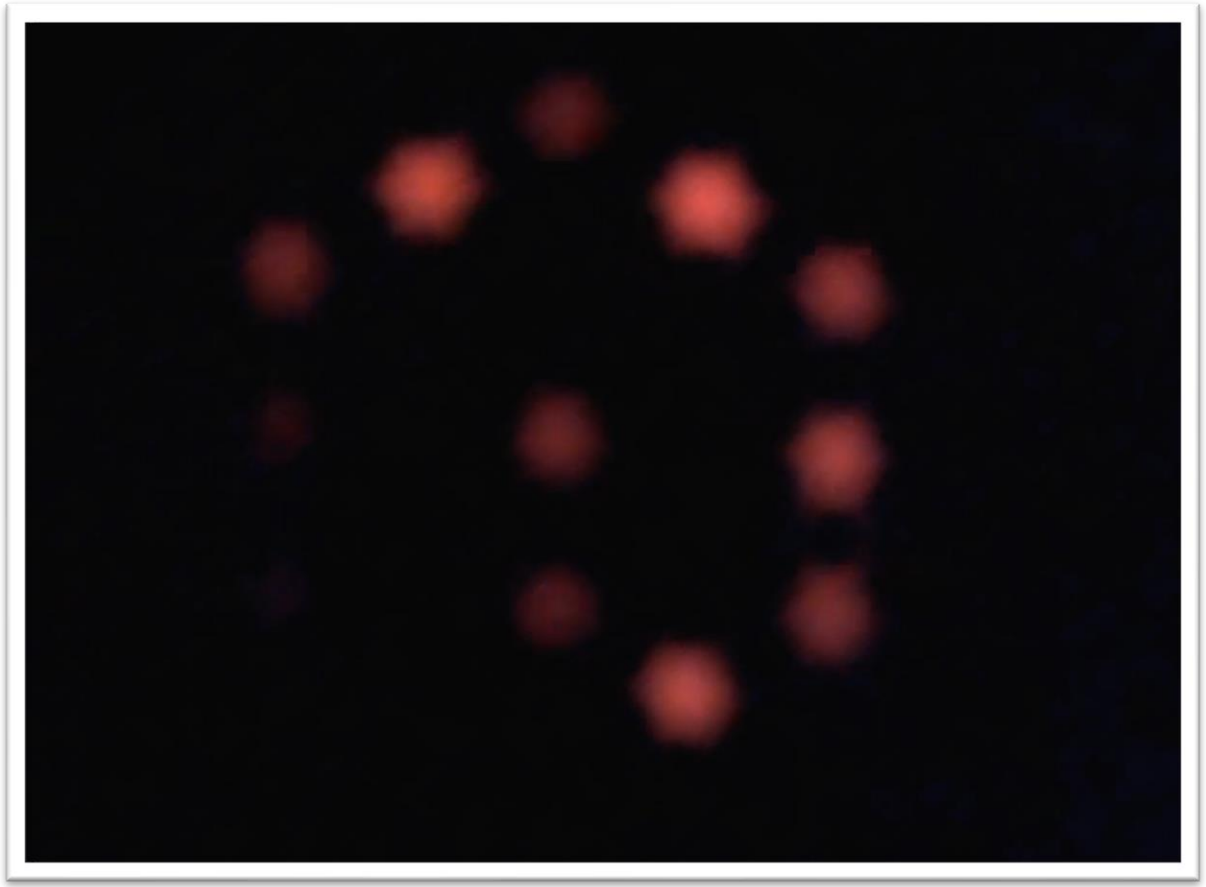
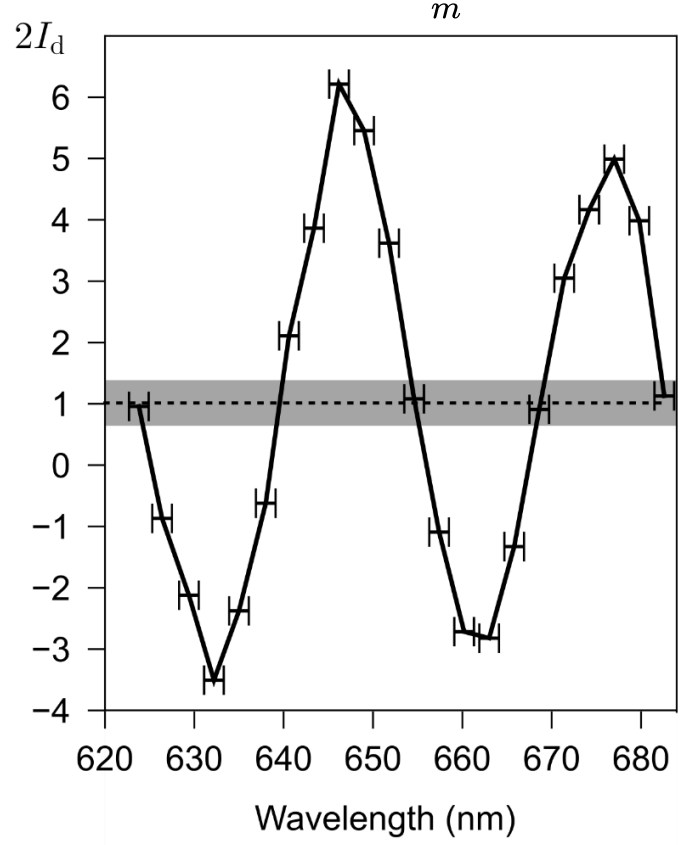


Varying input wavelength 600nm – 650 nm

$$\nu = 2\langle I_d \rangle_\lambda = 2\langle \sum_m m(I_A - I_B) \rangle_\lambda$$



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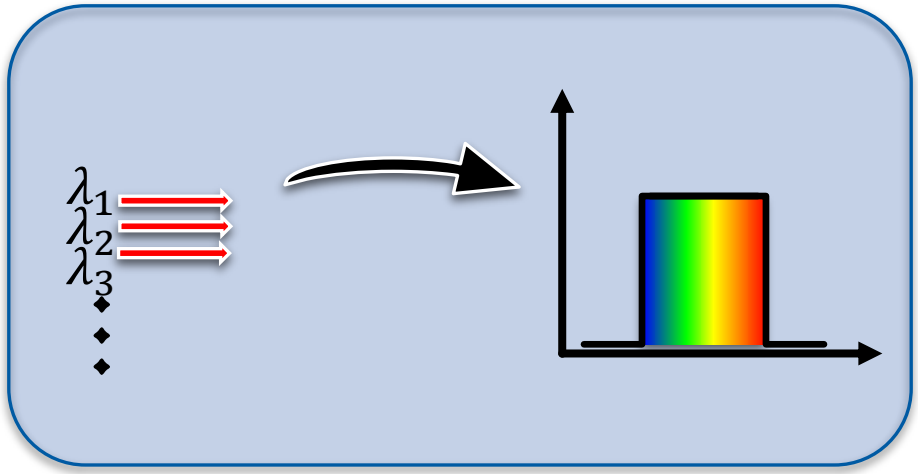

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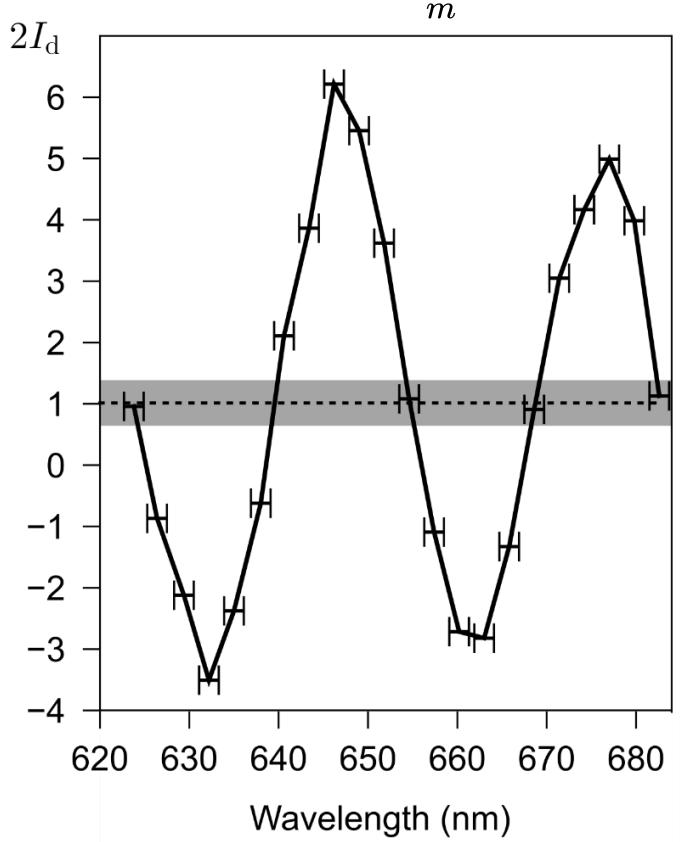

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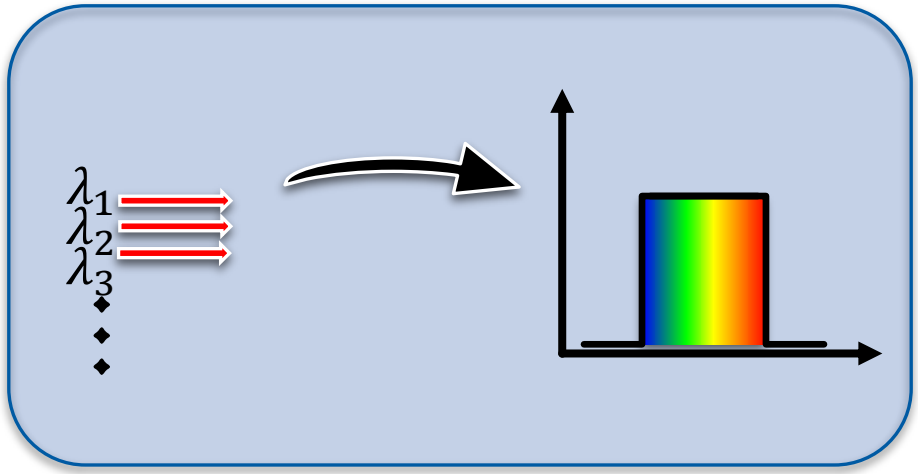
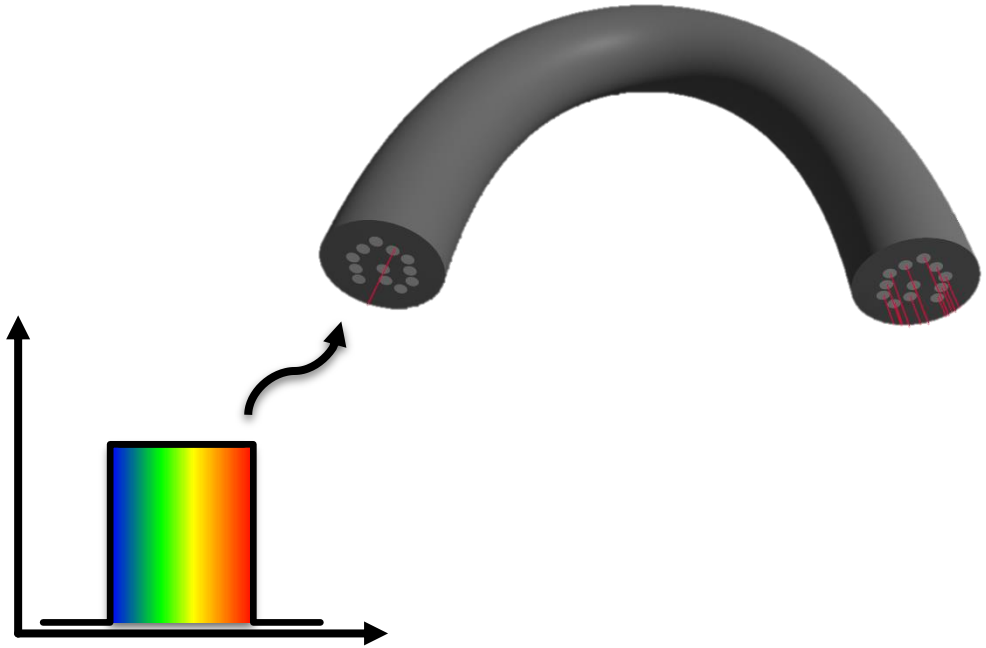
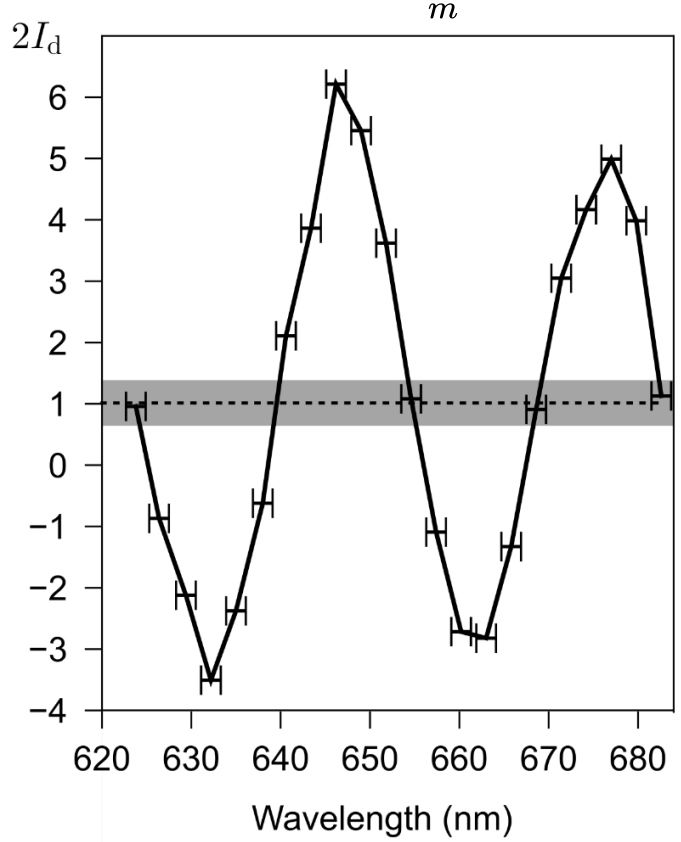




$$\nu = 2\langle I_d \rangle_\lambda = 2\langle \sum_m m(I_A - I_B) \rangle_\lambda$$



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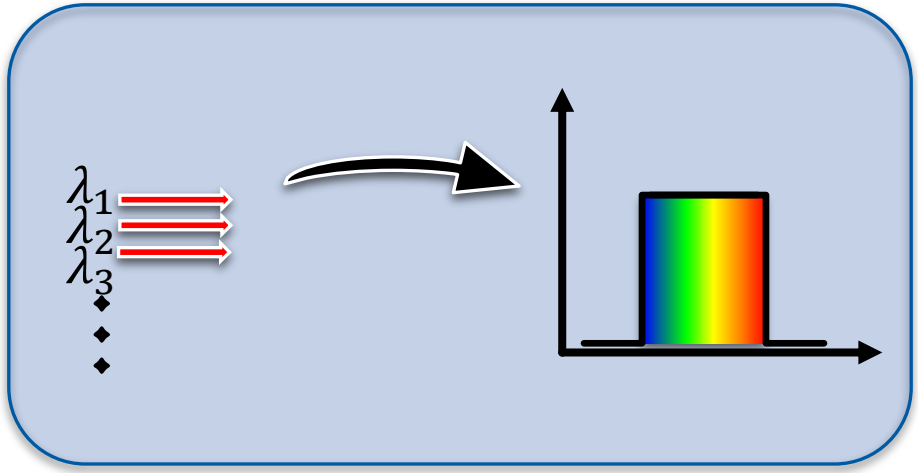
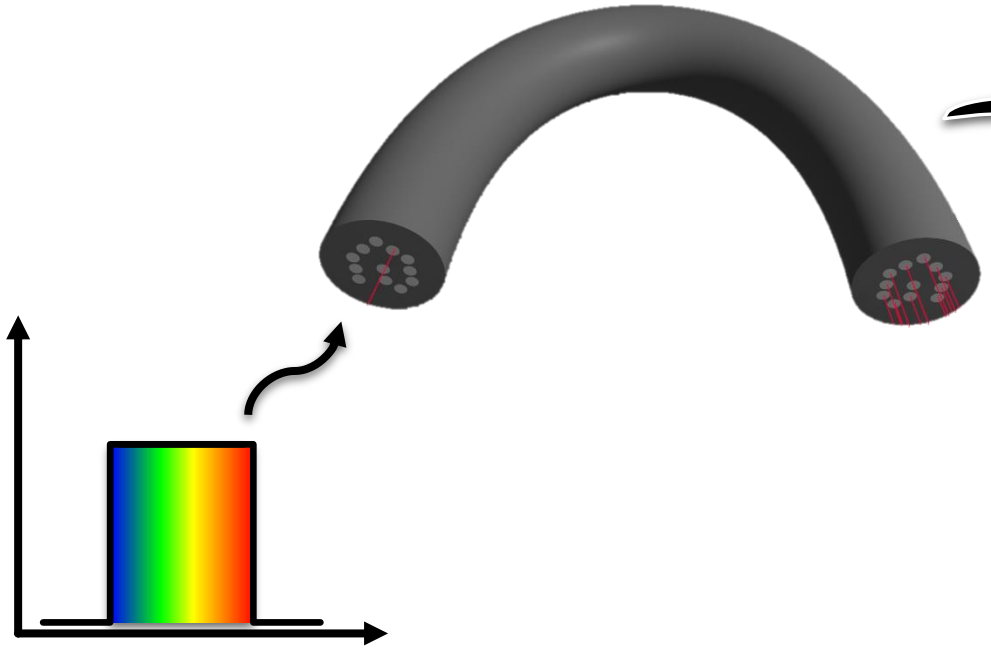
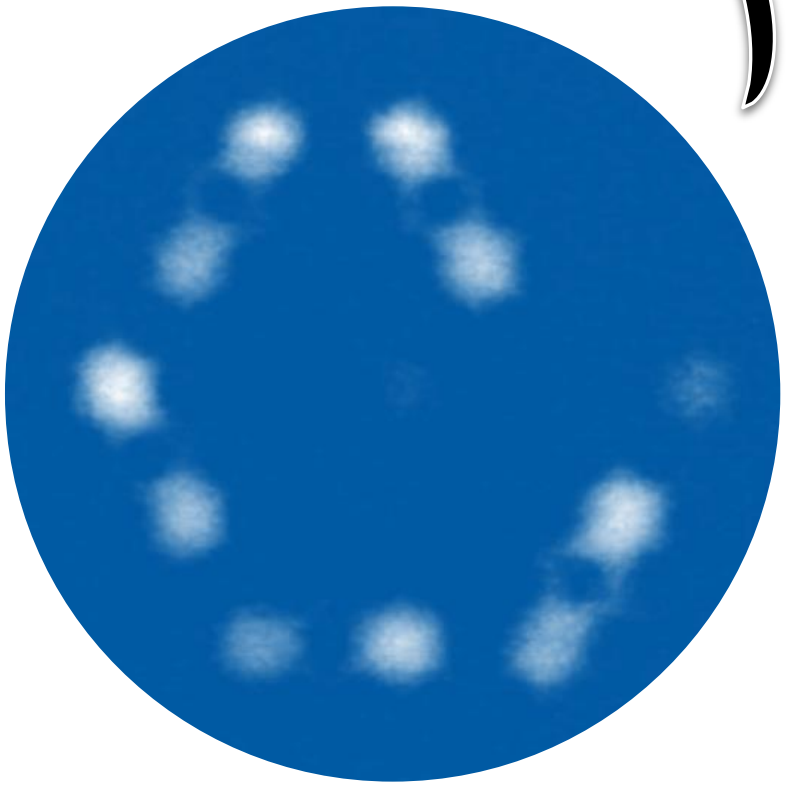


$$\nu = 2\sum_m (I_{Am} - I_{Bm})m$$





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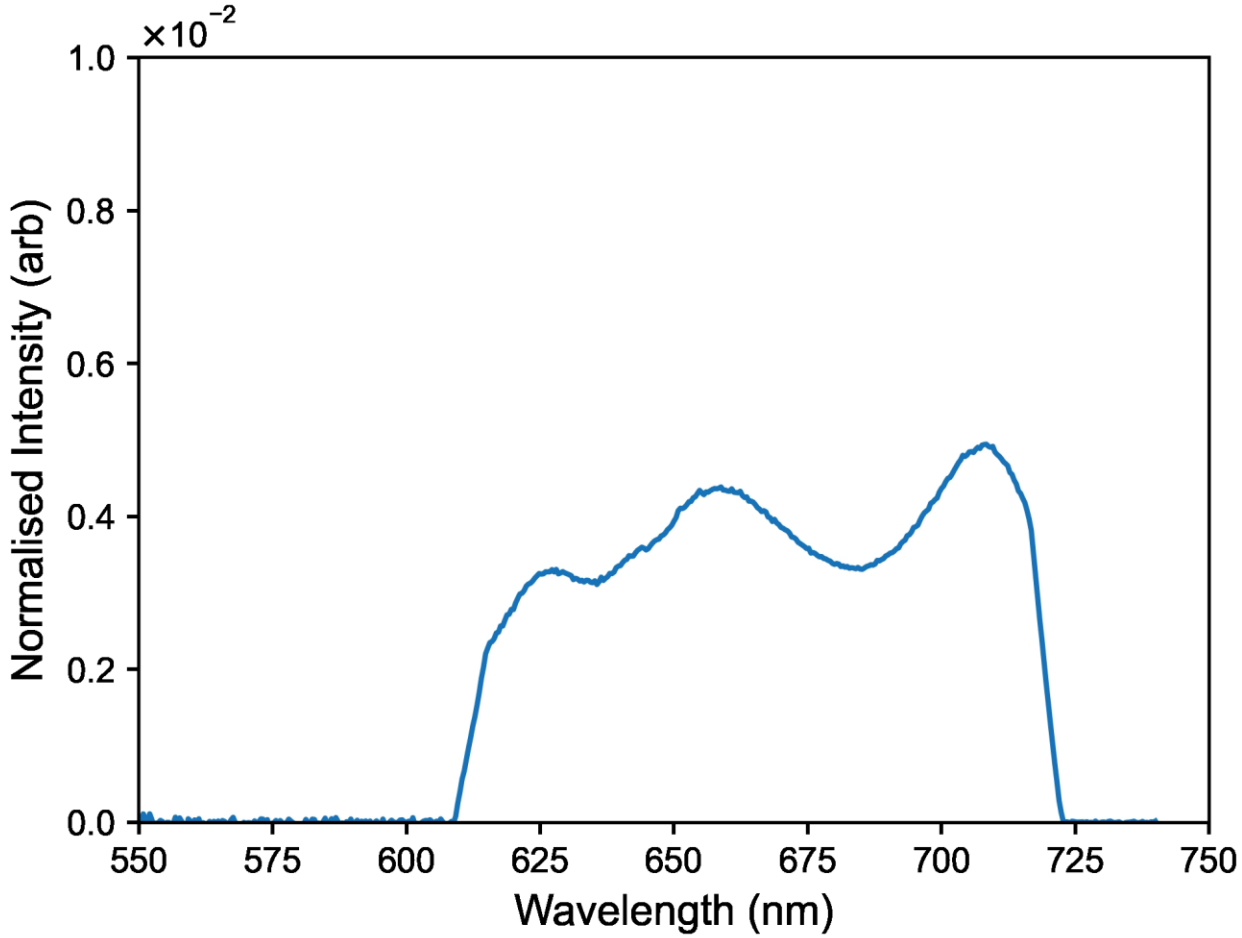

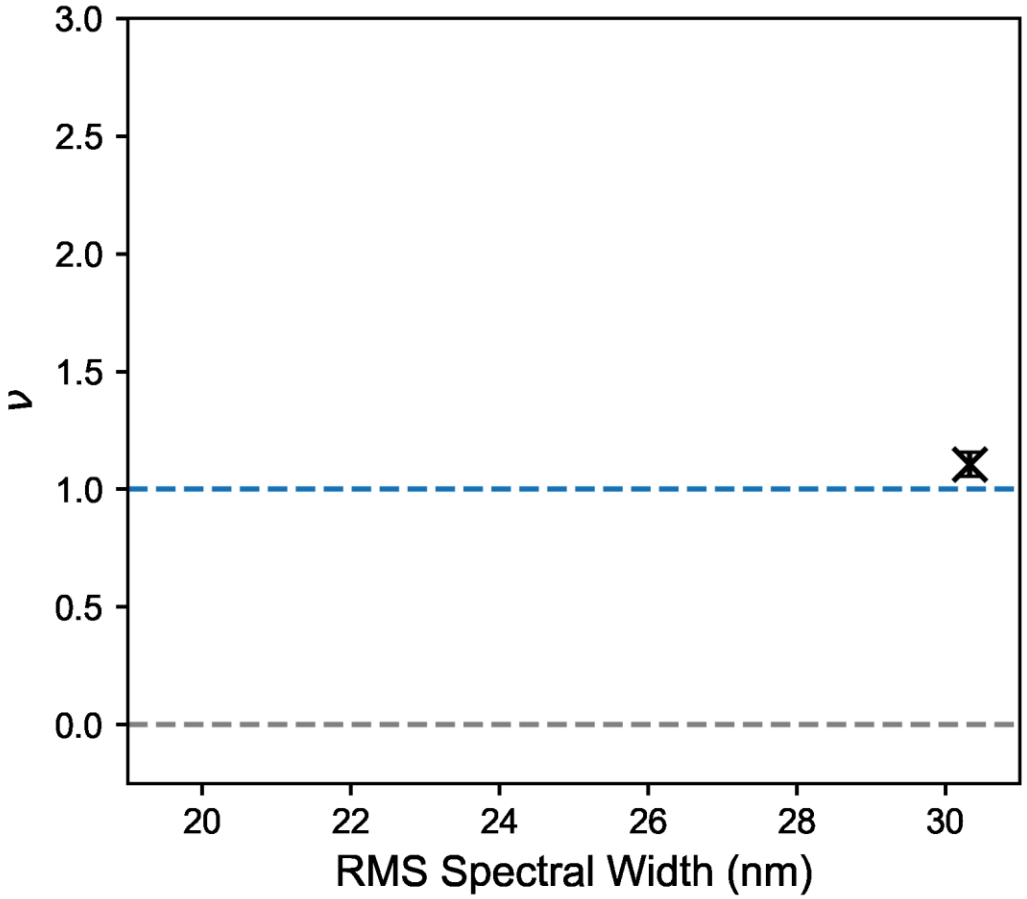

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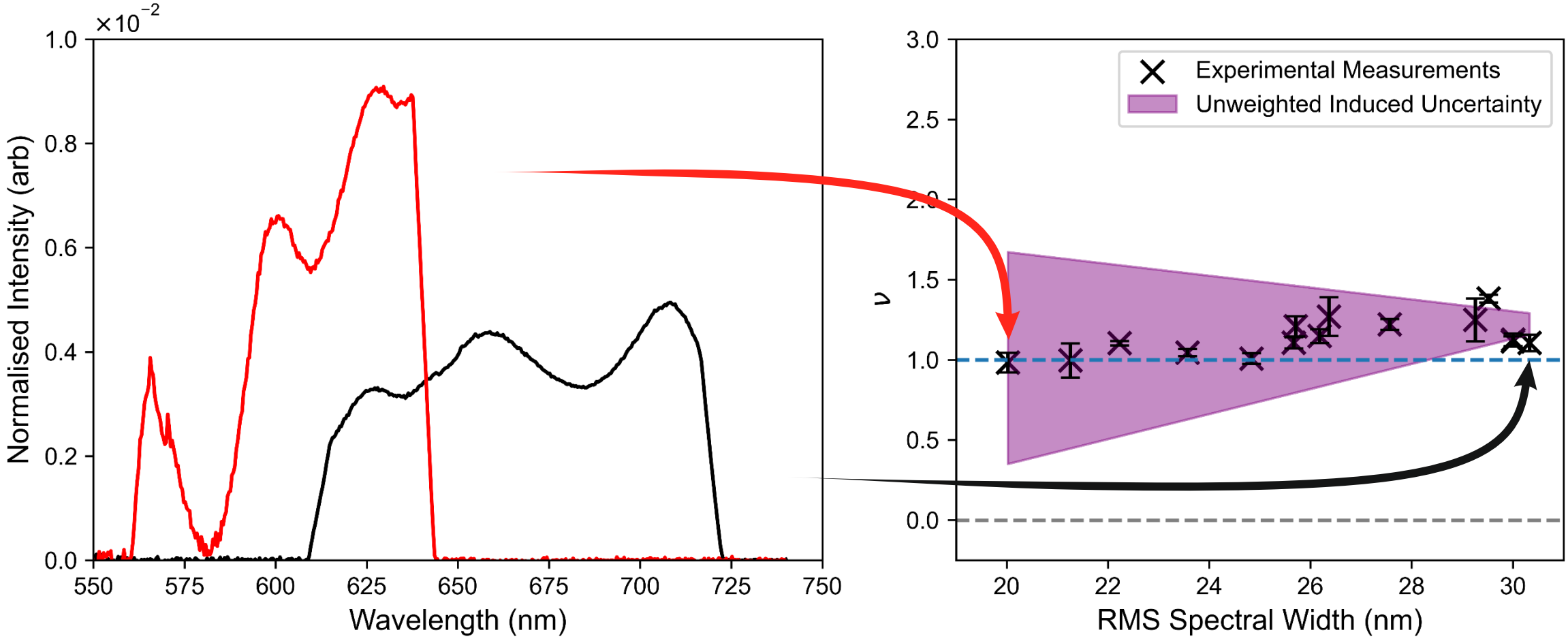
Invariant Calculation



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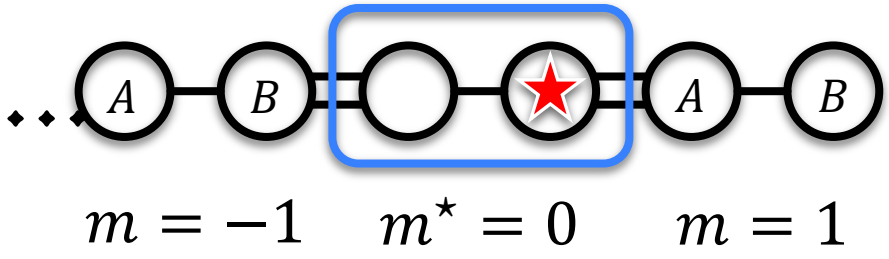
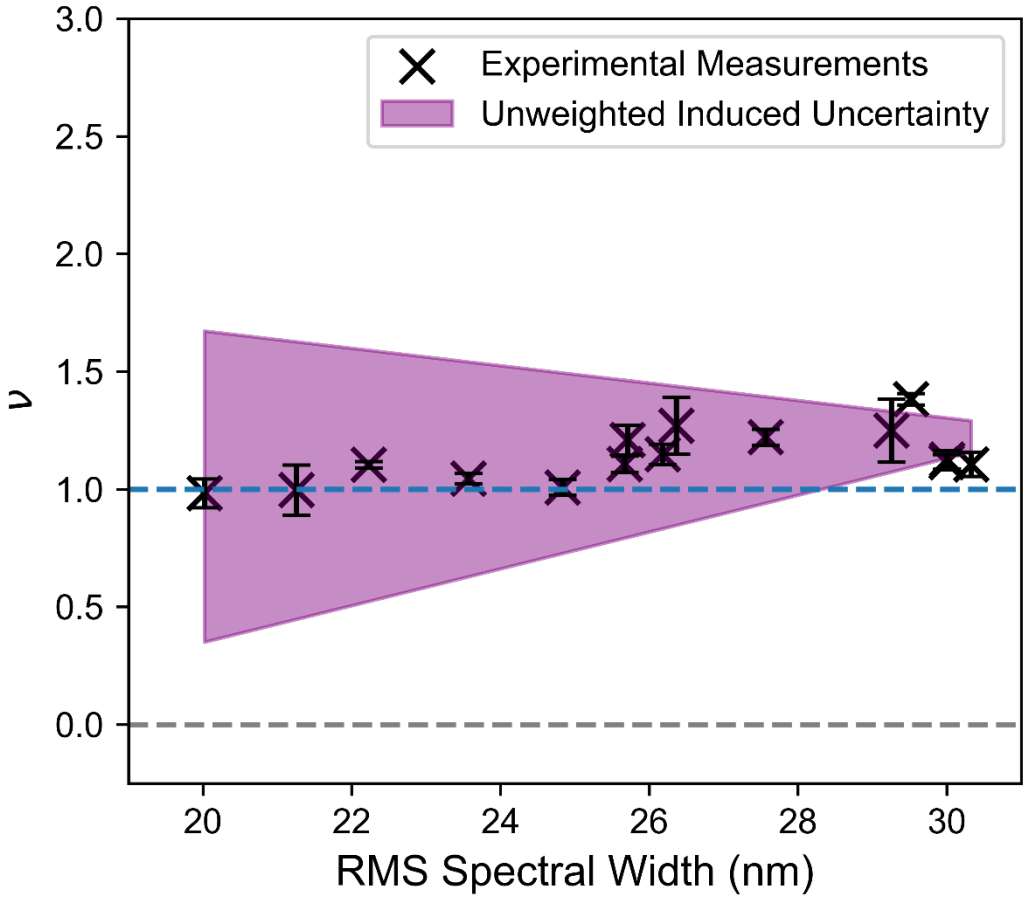
Invariant Calculation

$$2I_d = \nu + m^\star \sum_m (I_{Am} - I_{Bm})$$





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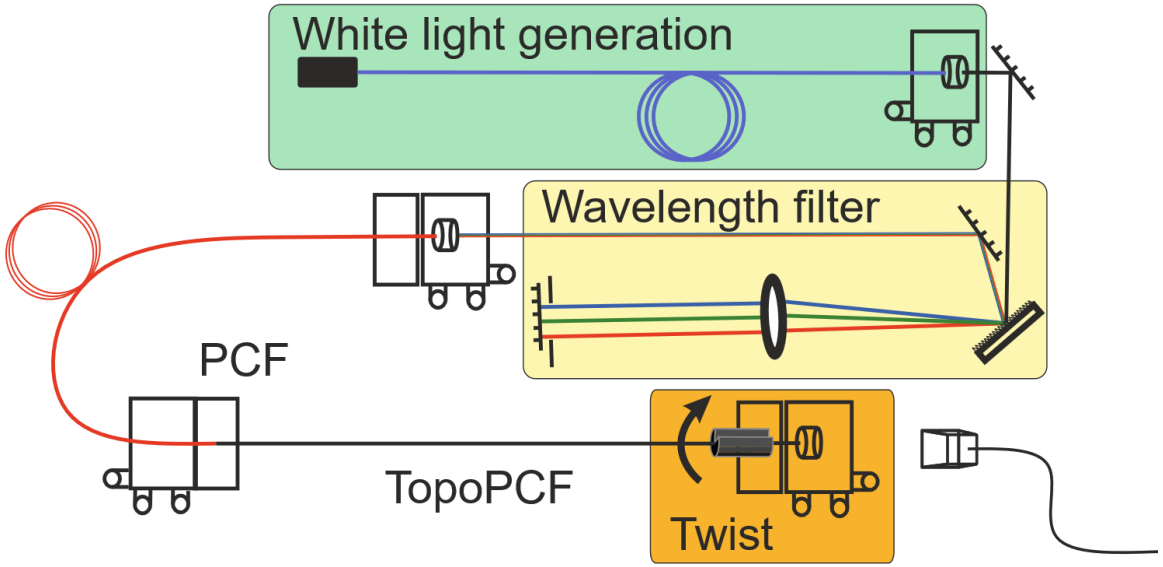
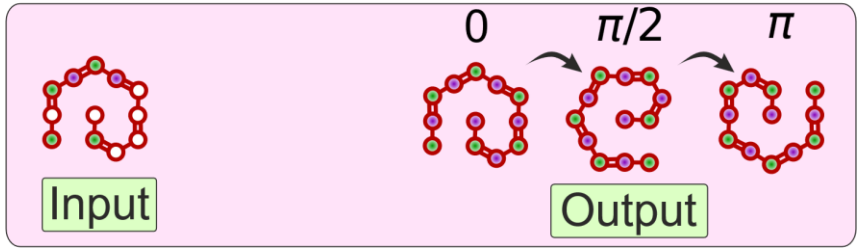
Bending and Twisting





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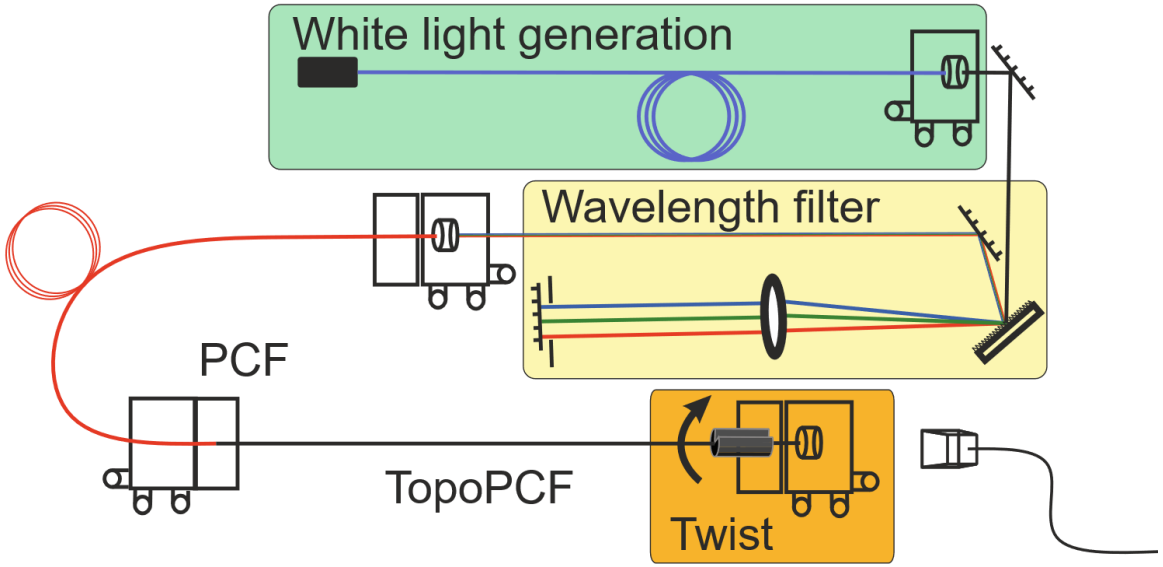
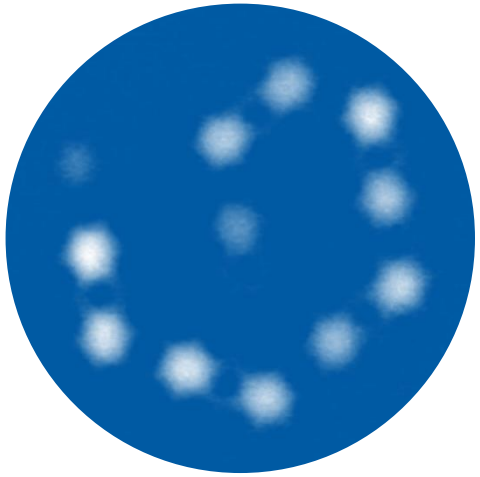
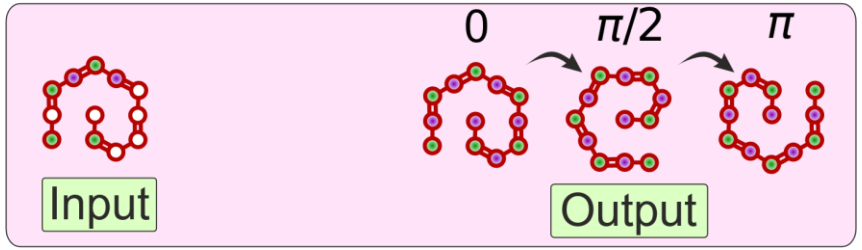
Bending and Twisting







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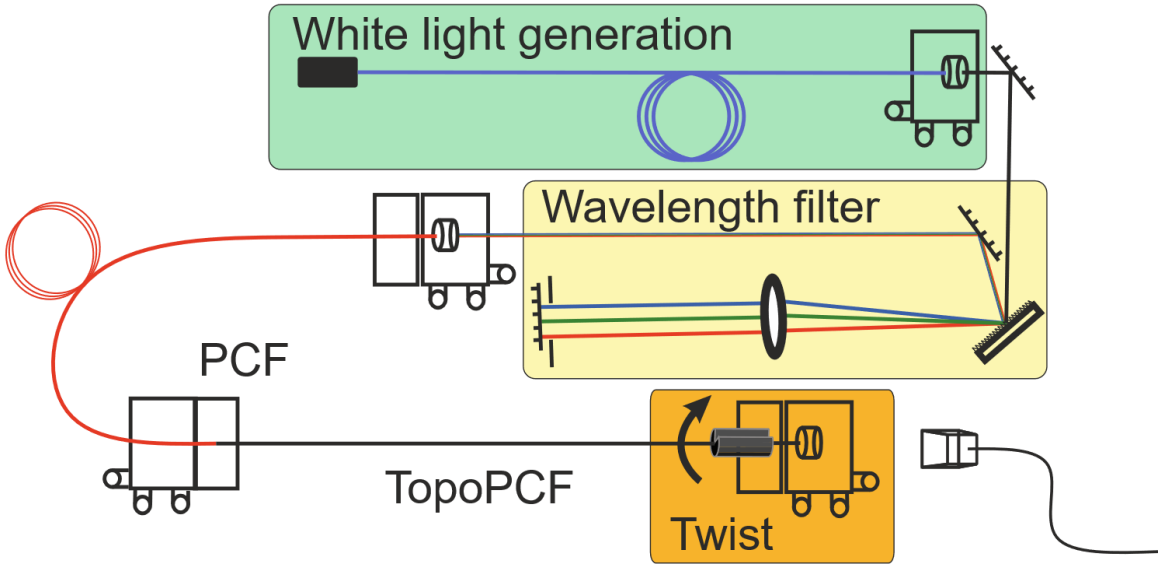

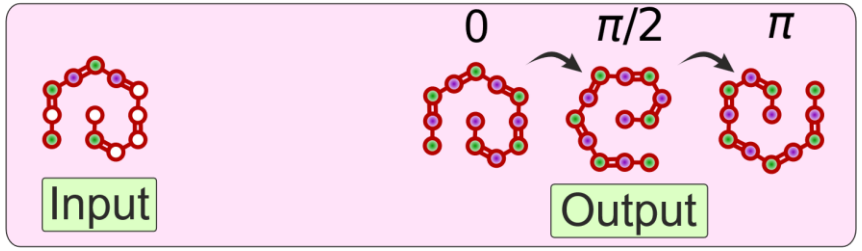

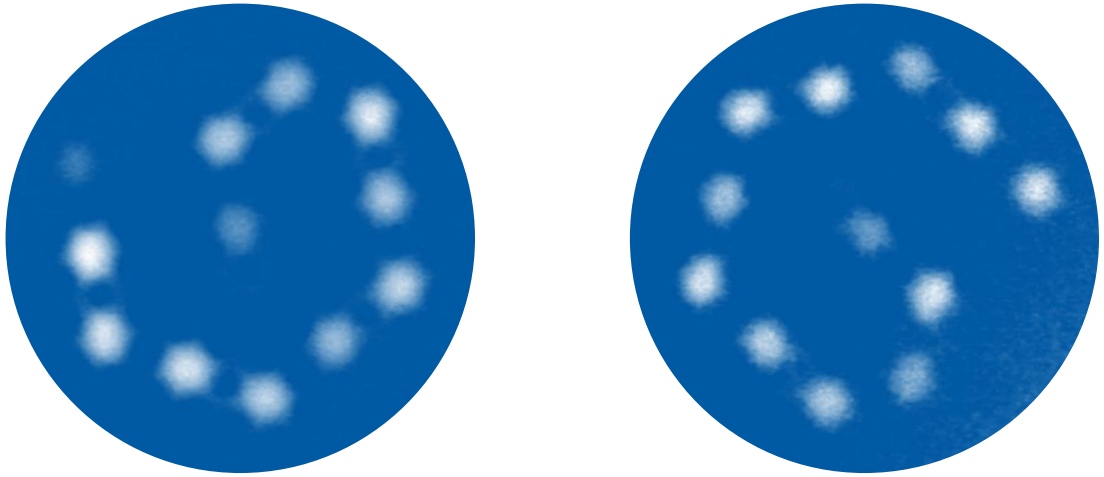

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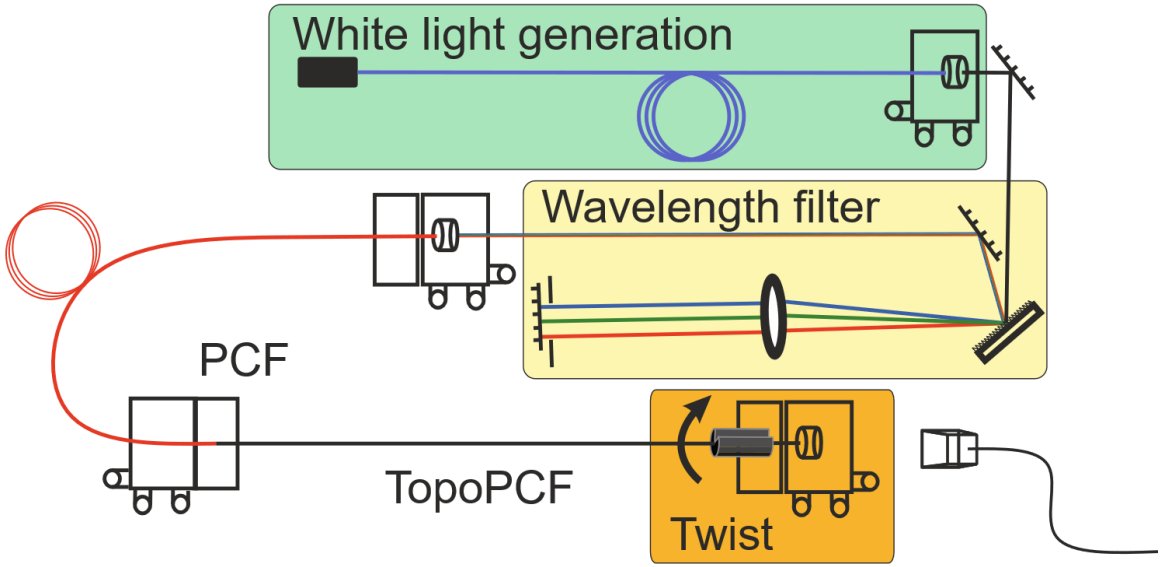

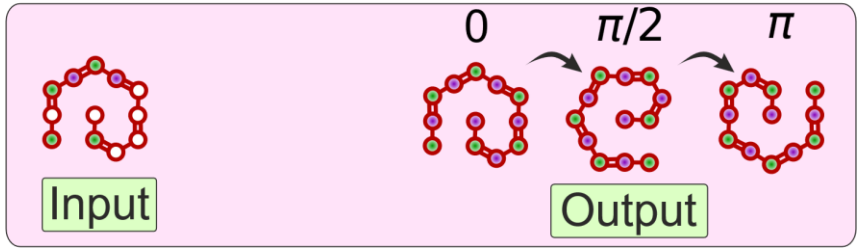

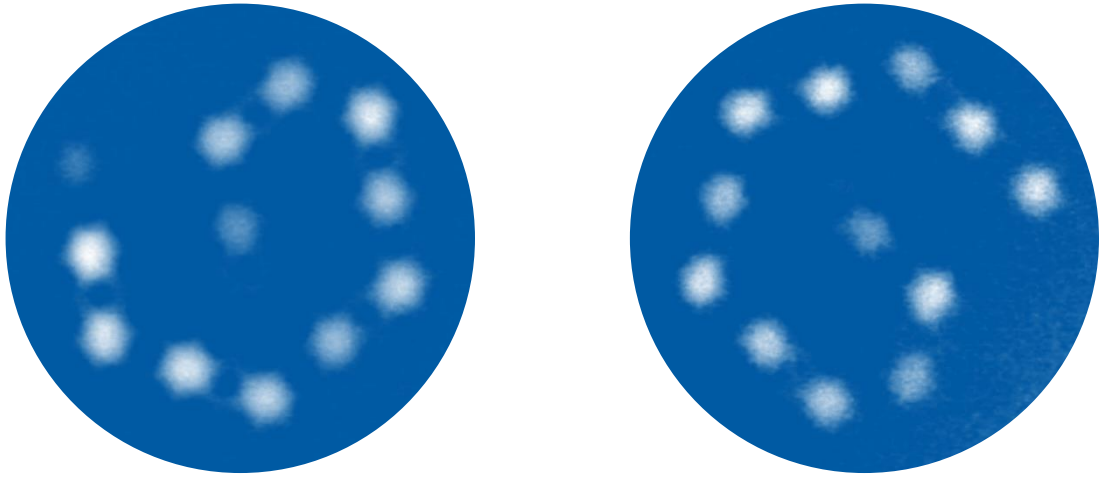

Topological

Trivial

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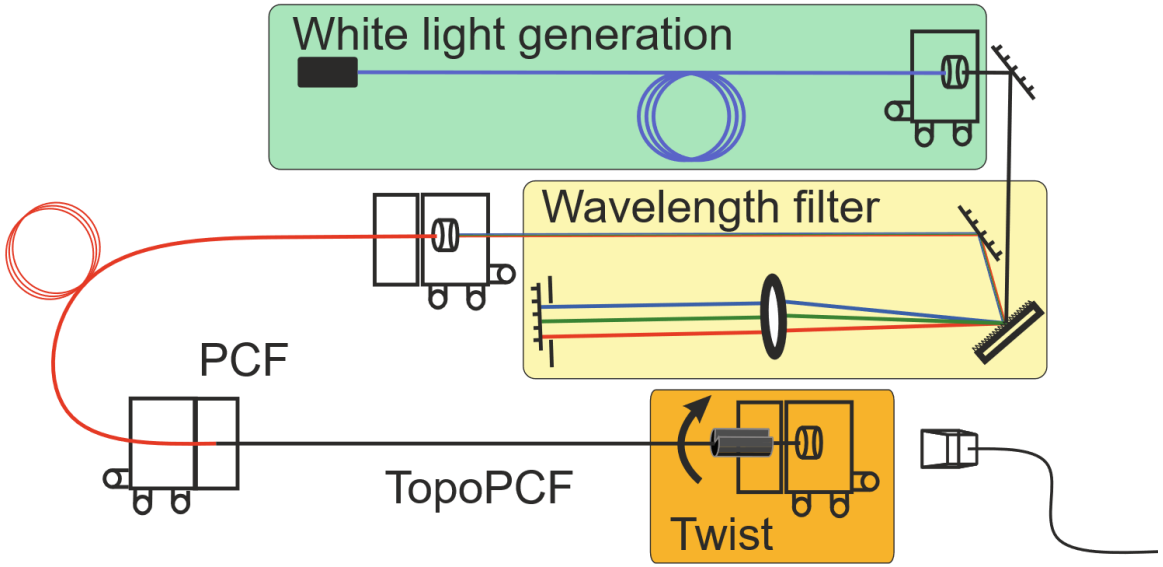
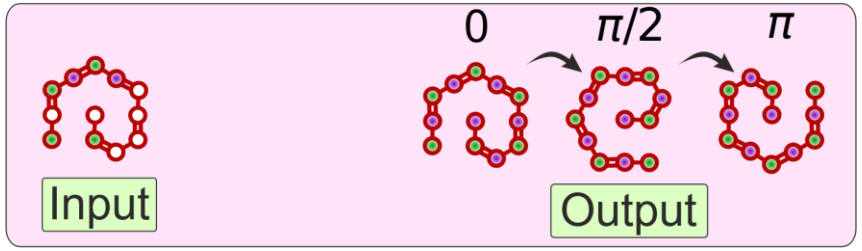
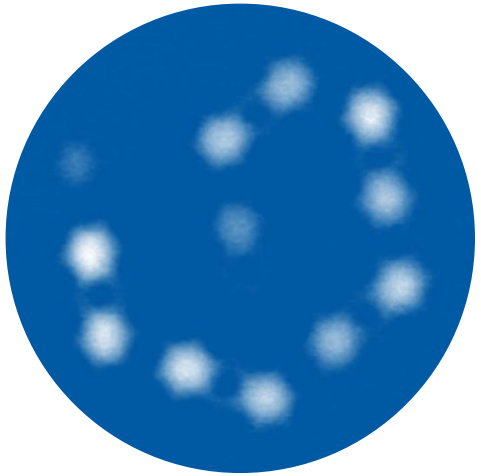
Bending and Twisting







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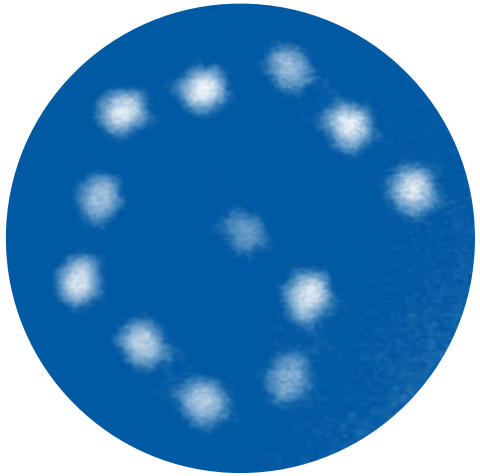

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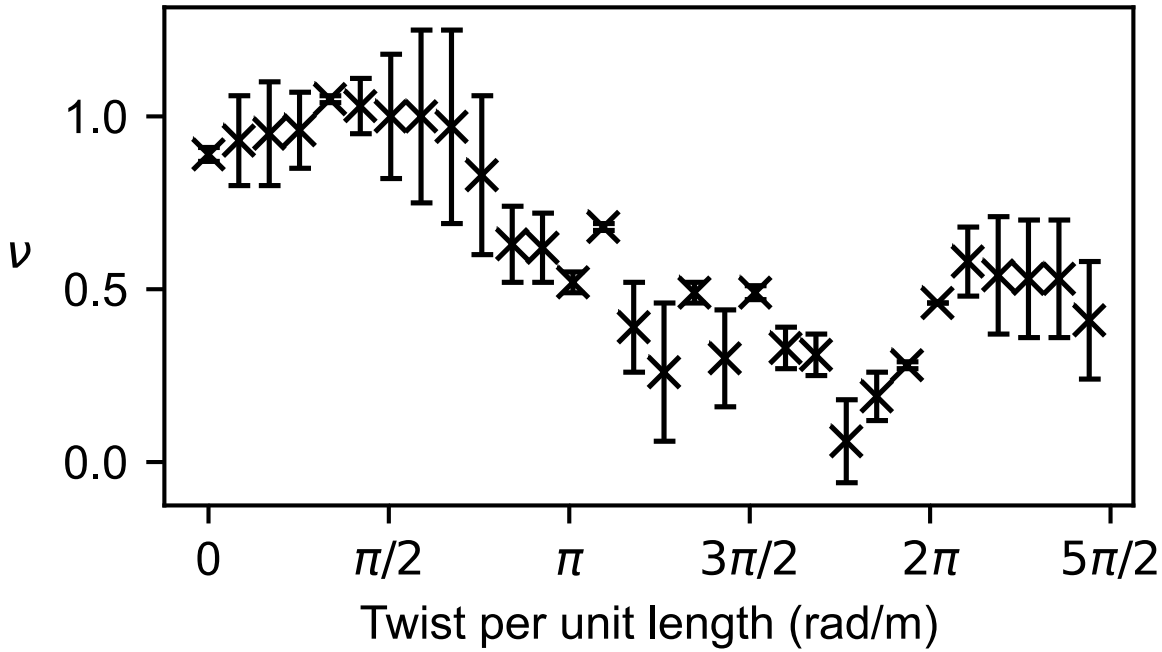

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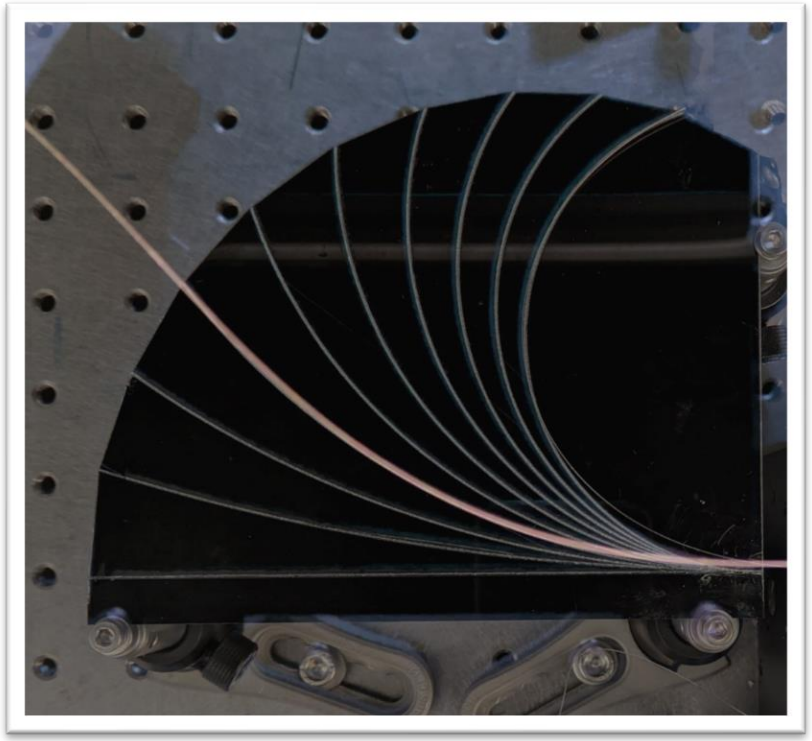

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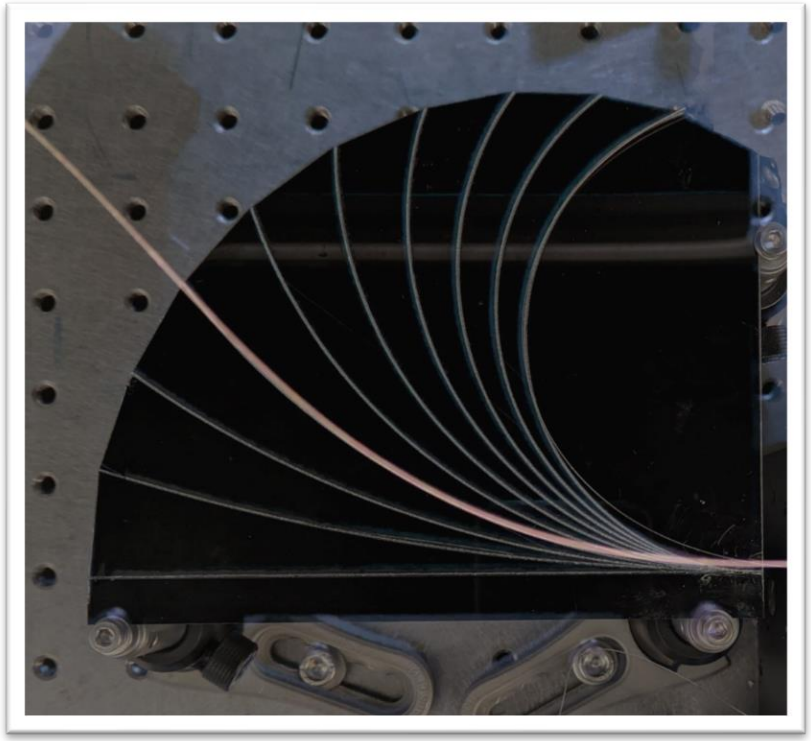

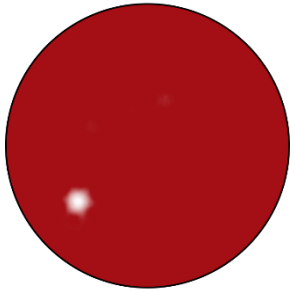

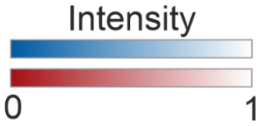

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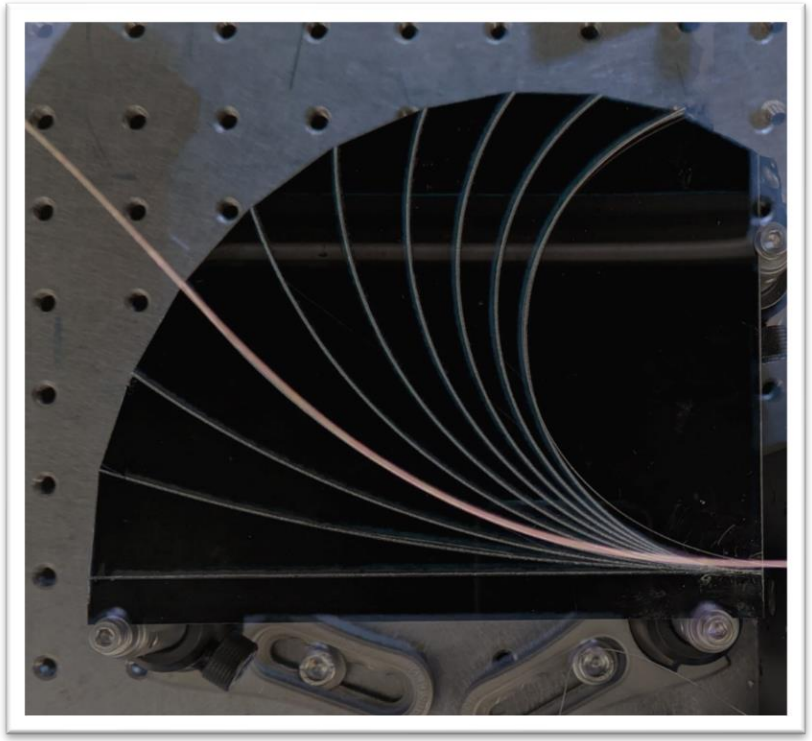

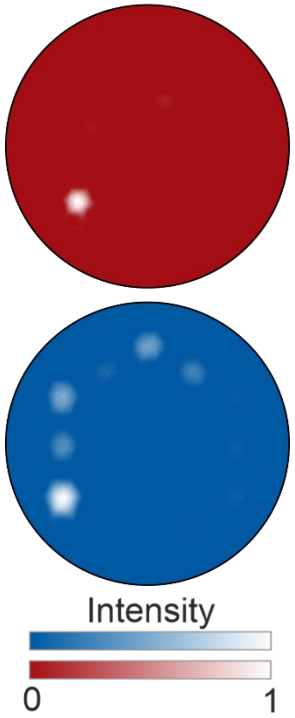

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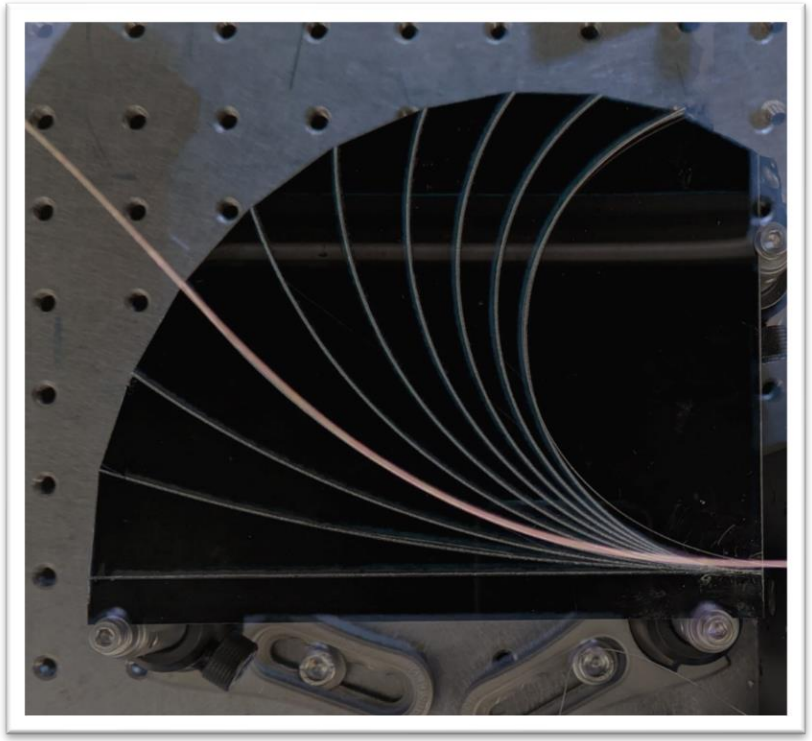

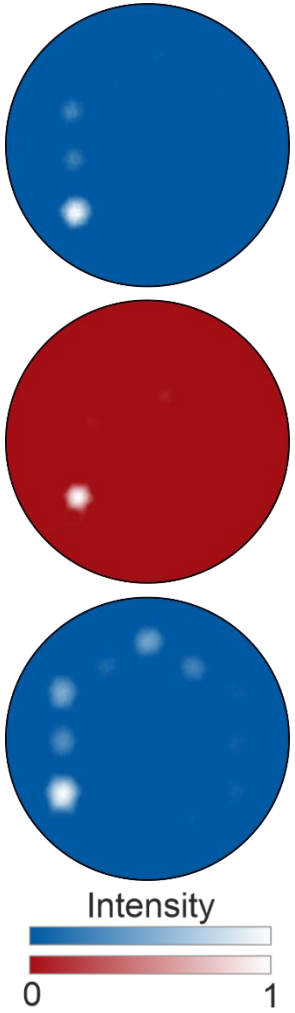

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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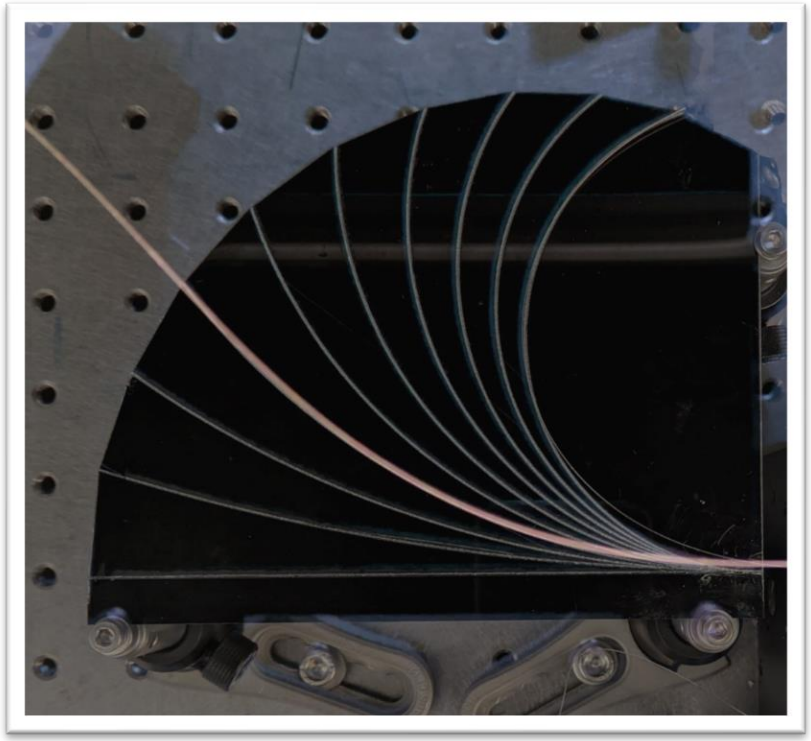
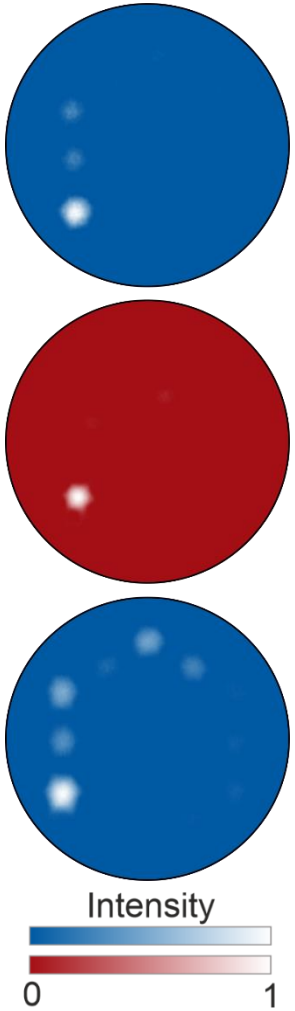
Bending and Twisting





Inverse Participation Ratio

$$\mathrm{IPR} = \frac{\sum_k I_k^2}{(\sum_k I_k)^2}$$

Sum over all cores

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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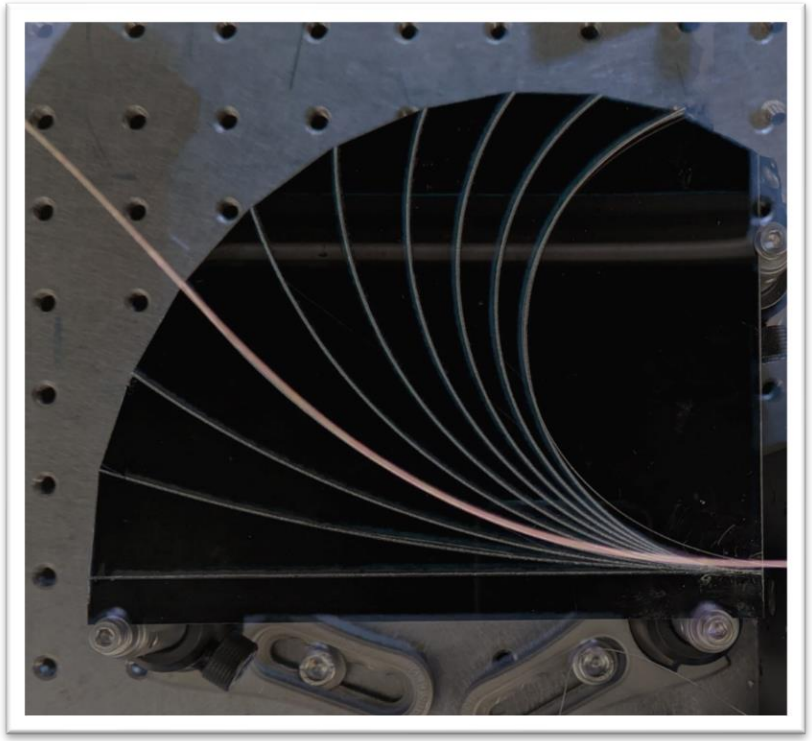
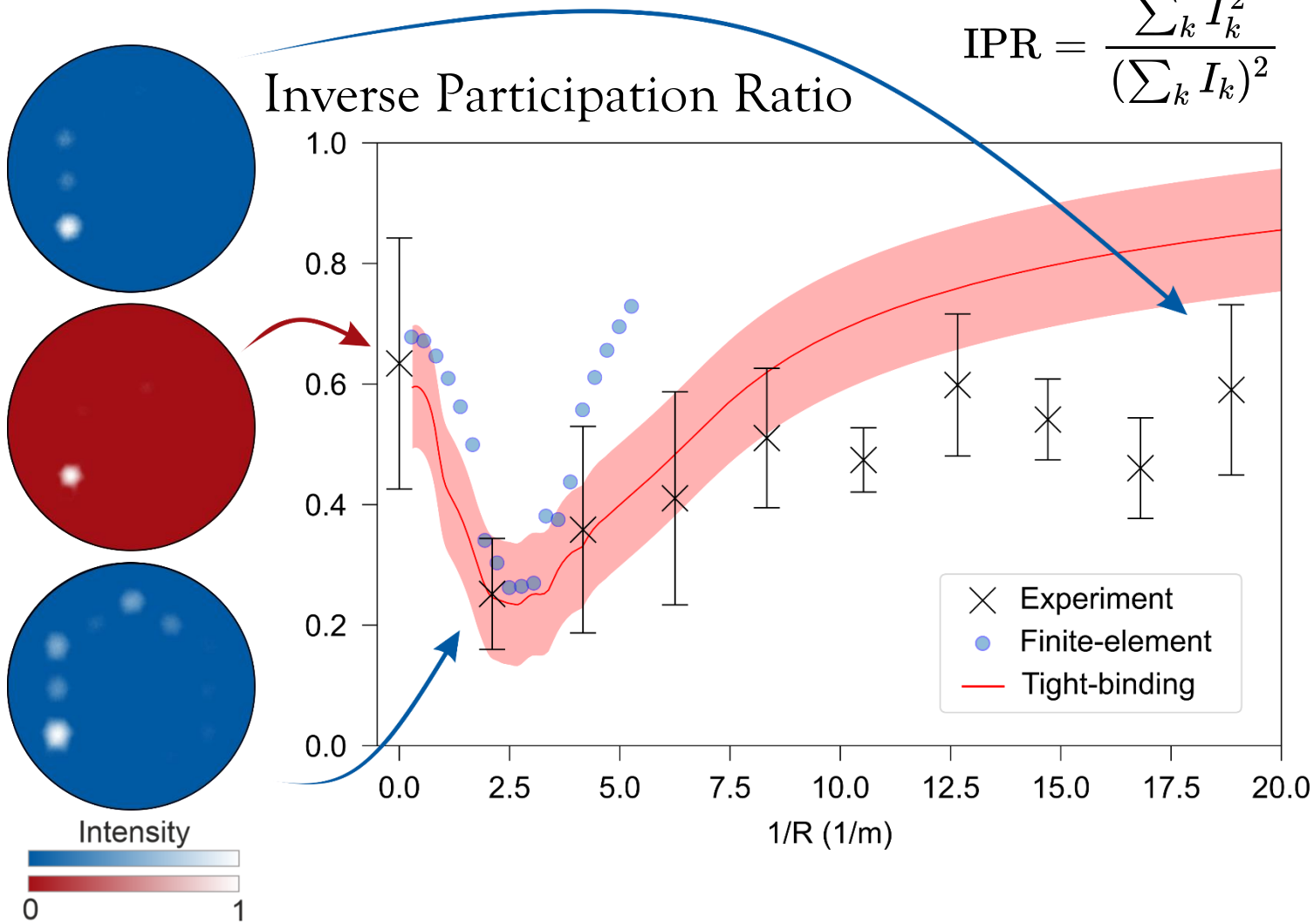
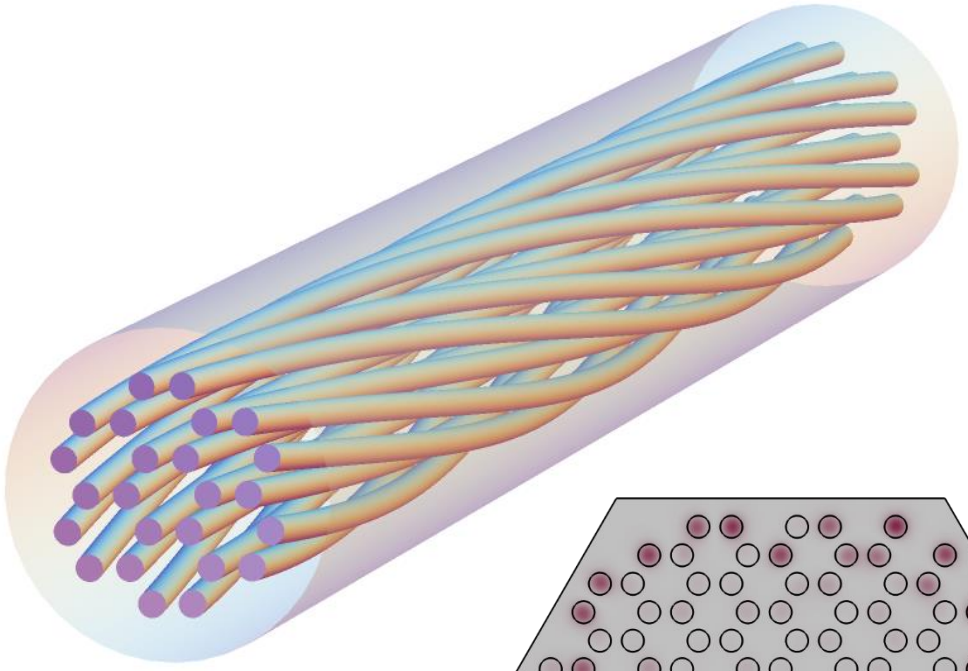
Bending and Twisting

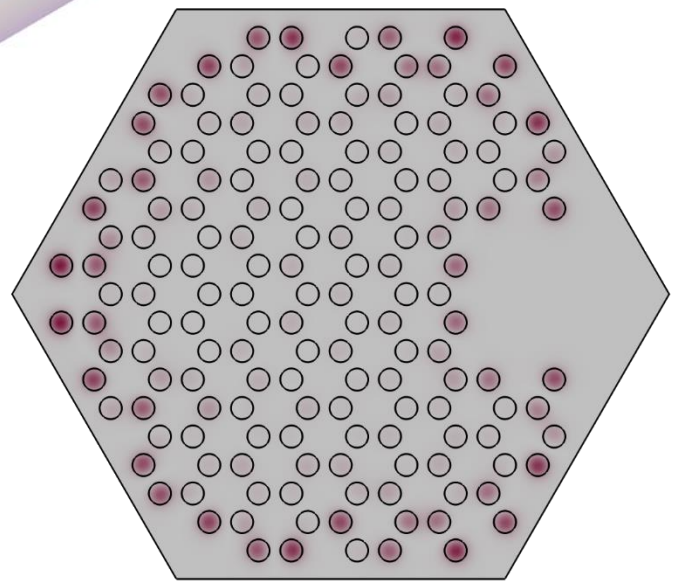


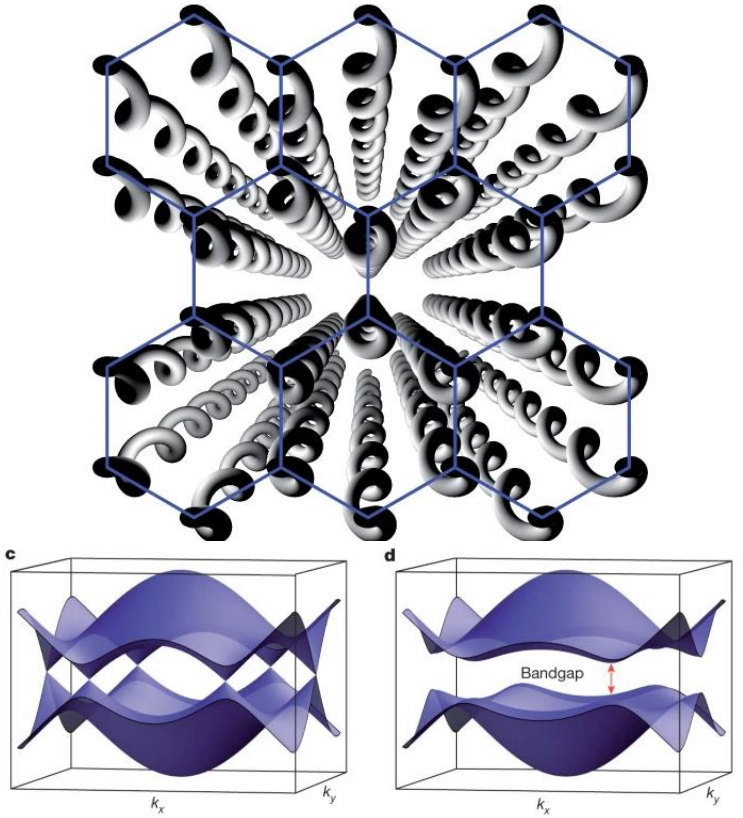


Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

Bending and Twisting







Rechtsman, M. et al.
Photonic Floquet Topological Insulators.
Nature **496**

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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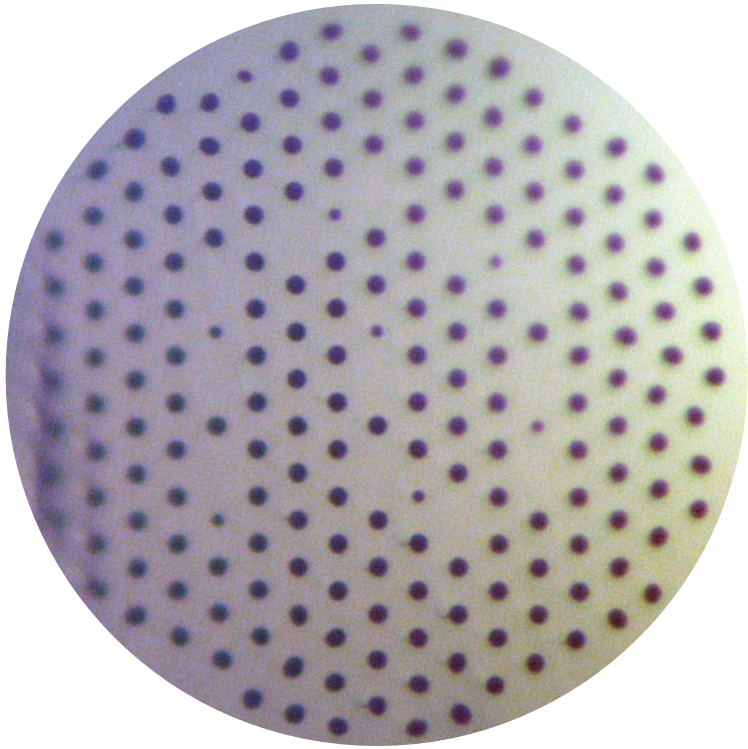
Optical fibre:

A new platform to explore topological photonics



Topological supermodes in photonic crystal fibre,
Science Advances 8, eadd3522 (2022)

Single-shot measurement of photonic topological invariant,
arXiv:2305.03630 (2023)

Nathan Roberts, Guido Baardink, Josh Nunn,

Peter J Mosley, Anton Souslov

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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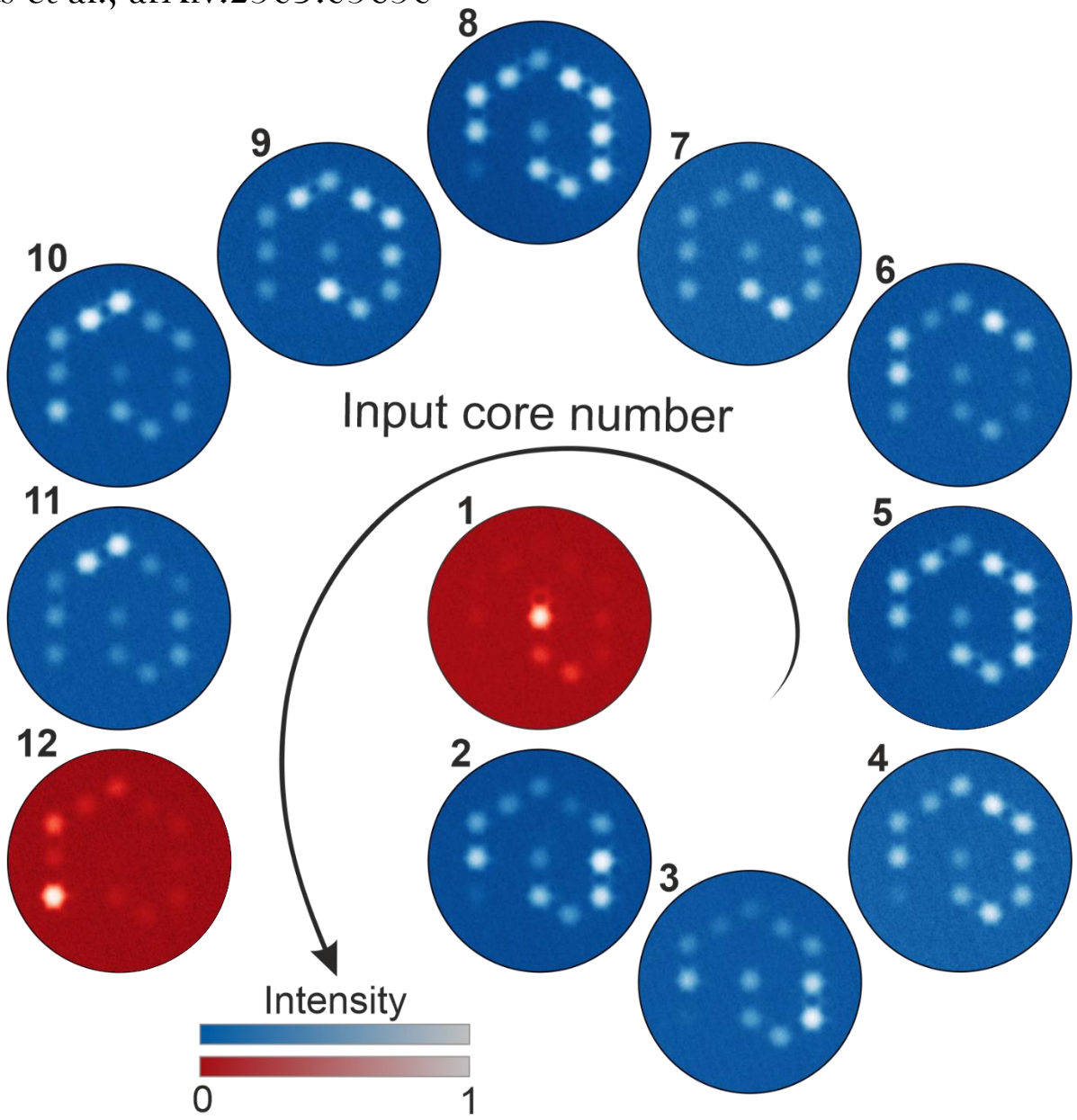

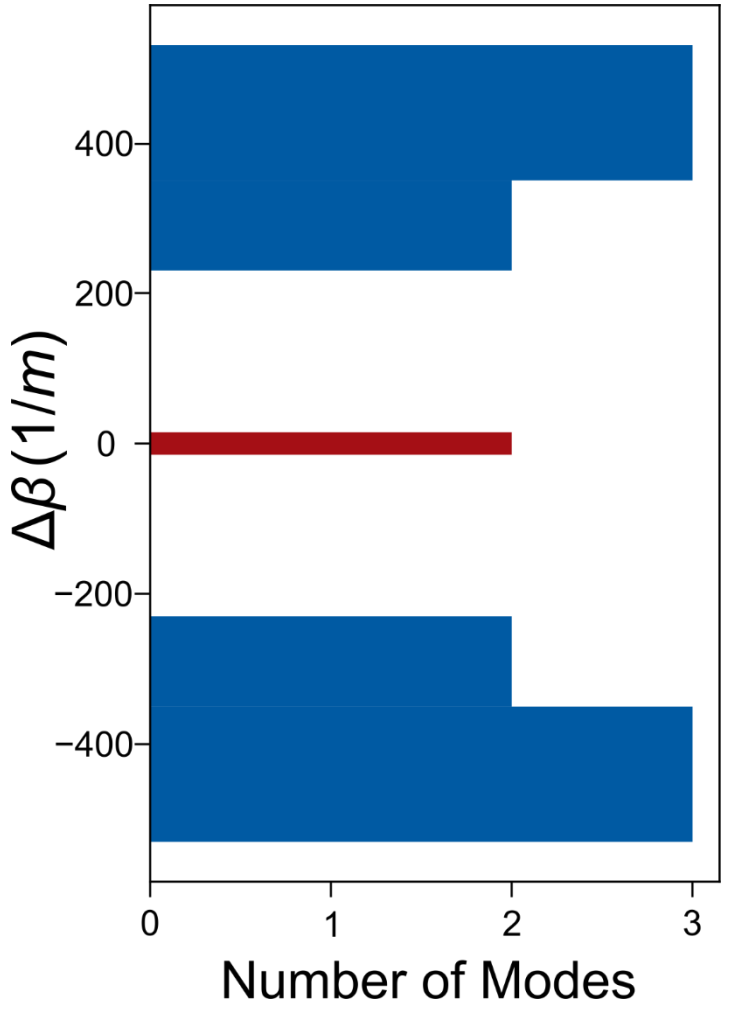

Roberts et al., *Sci. Adv.* 8 (2022),
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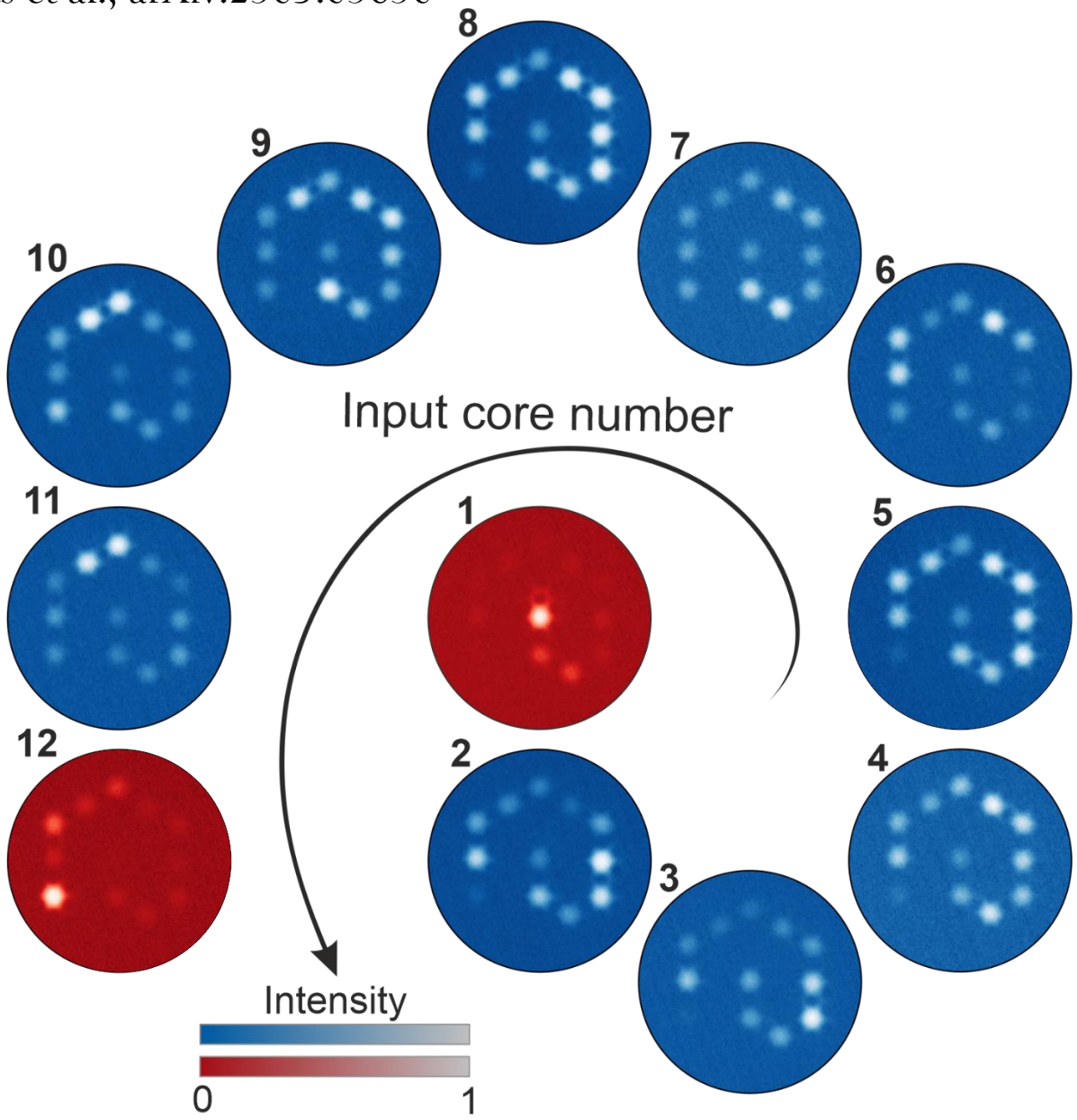

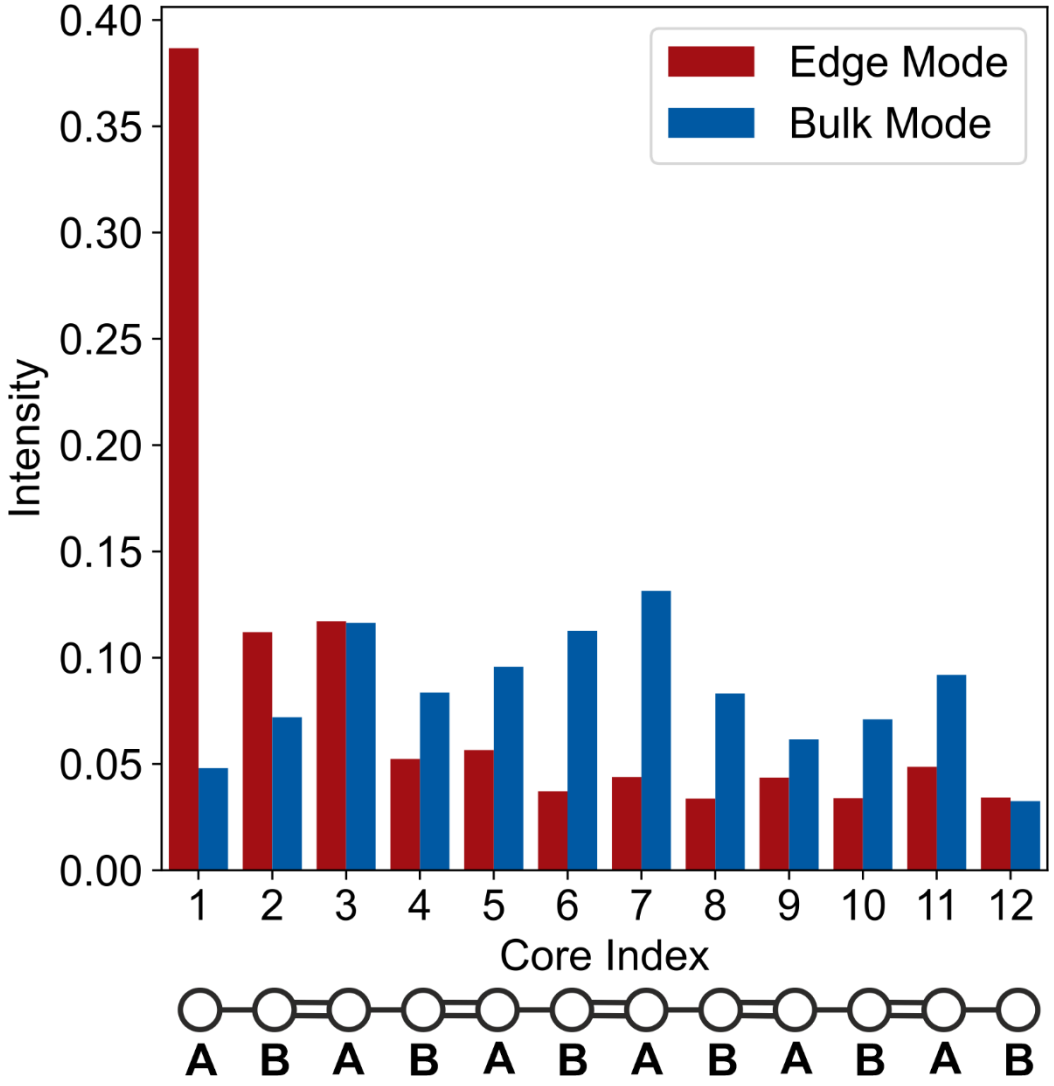

Roberts et al., *Sci. Adv.* **8** (2022),
Roberts et al., arXiv:2305.03630

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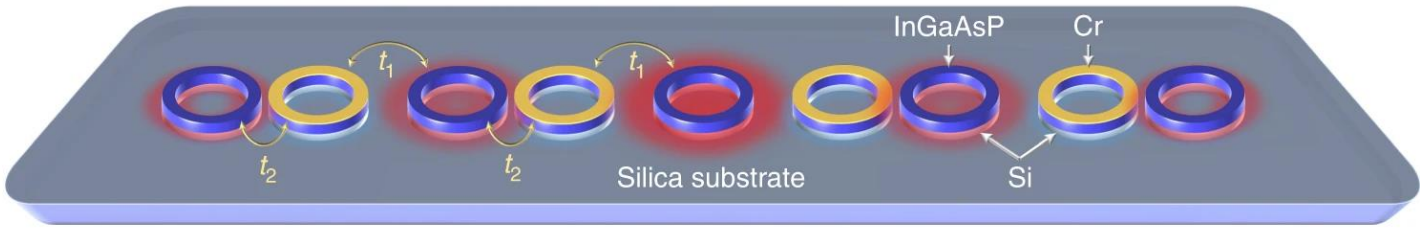
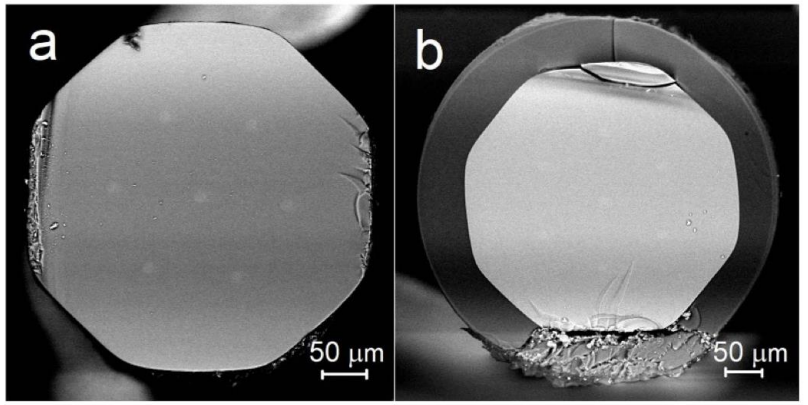
Future Directions



Zhao et al. 2018
Topological hybrid silicon microlasers
Nature Communications **9**

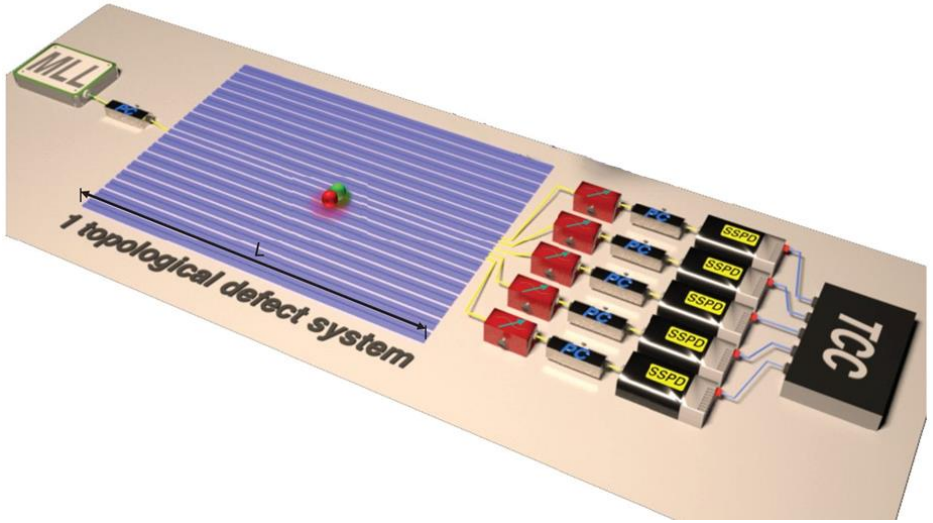


Franczyk et al. 2021
Multicore Yb3+ doped silica fibre laser
Laser Physics Letters **18**

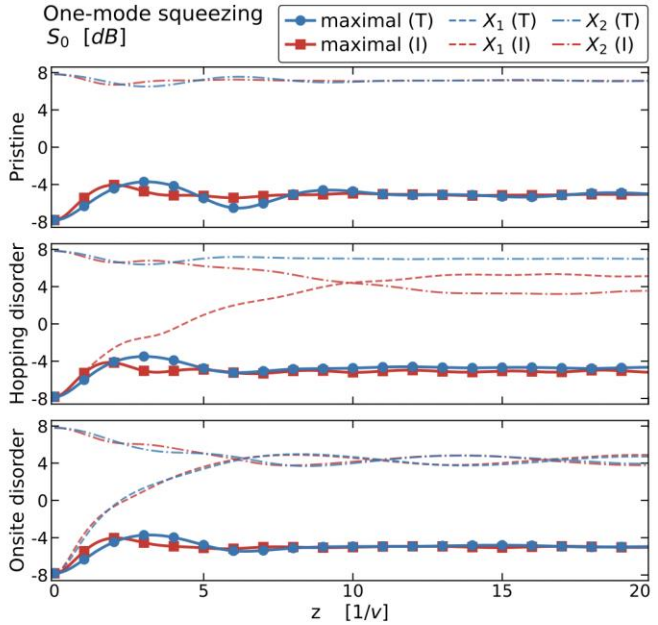
Topological Fibre Lasers

Roberts et al., *Sci. Adv.* **8** (2022),
Roberts et al., arXiv:2305.03630

Future Directions



A Blanco-Redondo et al. 2018
Topological protection of biphoton states
Science **362**



J Medina Duenas et al. 2021
Quadrature protection of squeezed states in a one-dimensional photonic topological insulator
Quantum **5**

Topological Disorder Protection of Quantum States

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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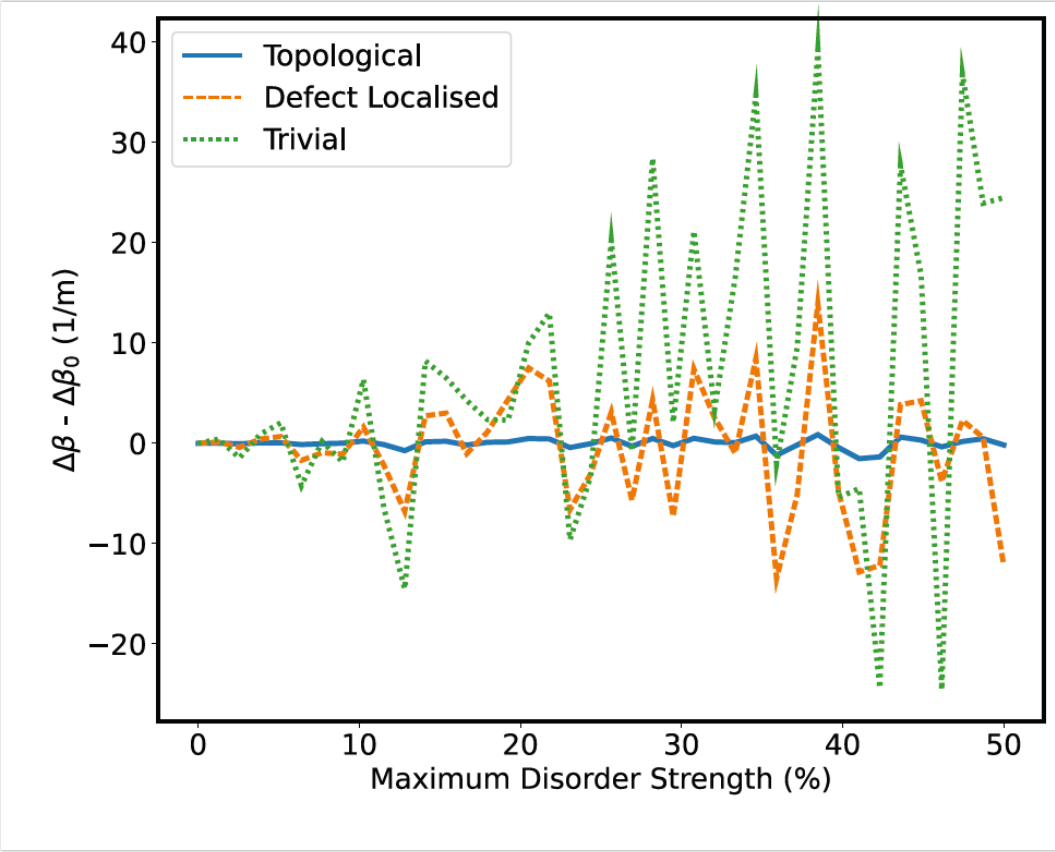
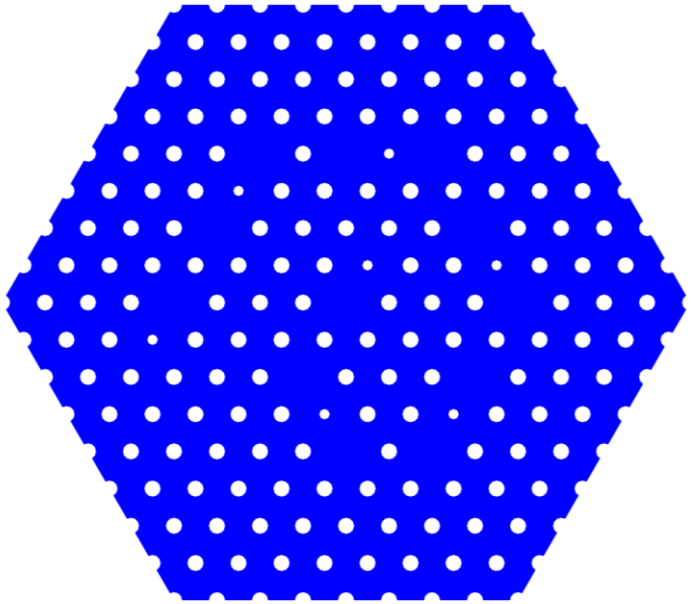
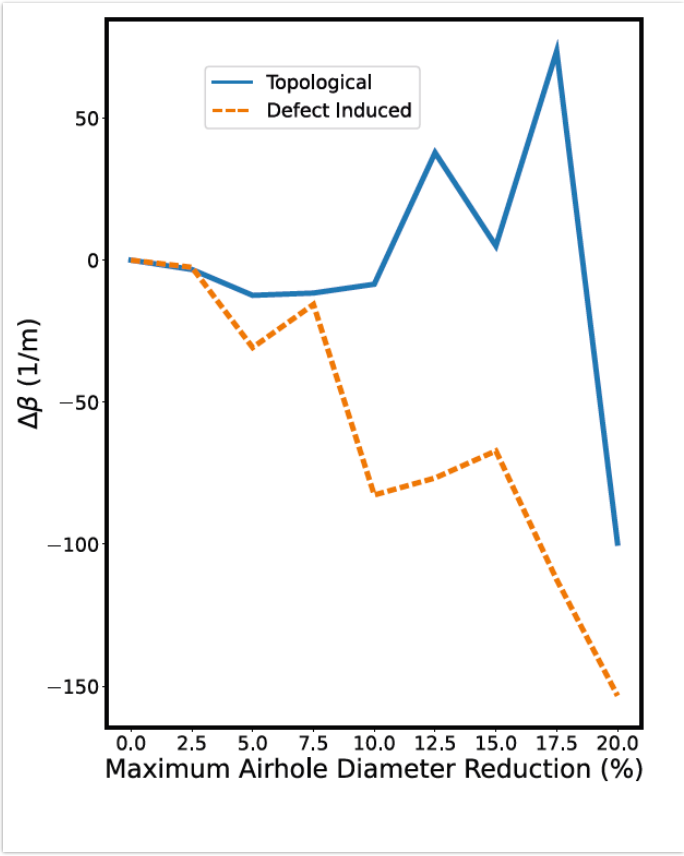
Protection Against Disorder



Analytic





Simulation

Roberts et al., *Sci. Adv.* **8** (2022),
Roberts et al., arXiv:2305.03630

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Optical Fibre

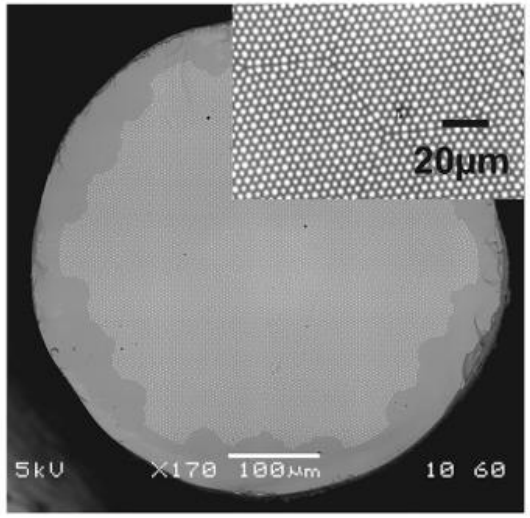
Photon-Pair Generation – O Cohen et al, *PRL* **102** 2009

Quantum Frequency Conversion– K A G Bonsma-Fisher et al, *PRL* **129** 2022

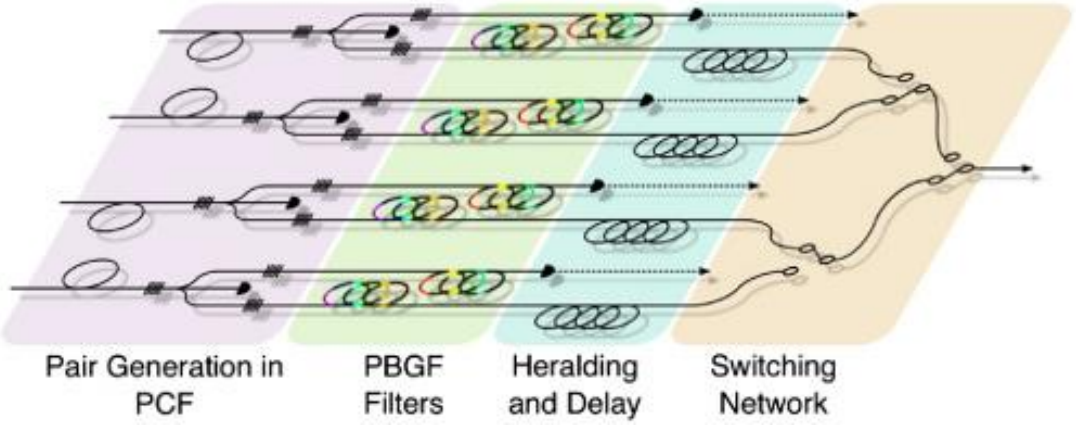
Supercontinuum Generation– L E Hooper et al, Opt. Express **19** 2011

Short Wavelength Guidance – J H Osório, *Nat. Comms.* **14** 2023

High Power Delivery – Q Fu, *Opt. Lett.* **47** 2022



J. M. Stone et al. 2017
Low index contrast imaging fibers
Opt. Lett. **42**



Robert J. A. Francis-Jones et al. 2016
All-fiber multiplexed source of high-purity single photons
Optica **3**

Optical fibre is the backbone of our global telecommunication networks.

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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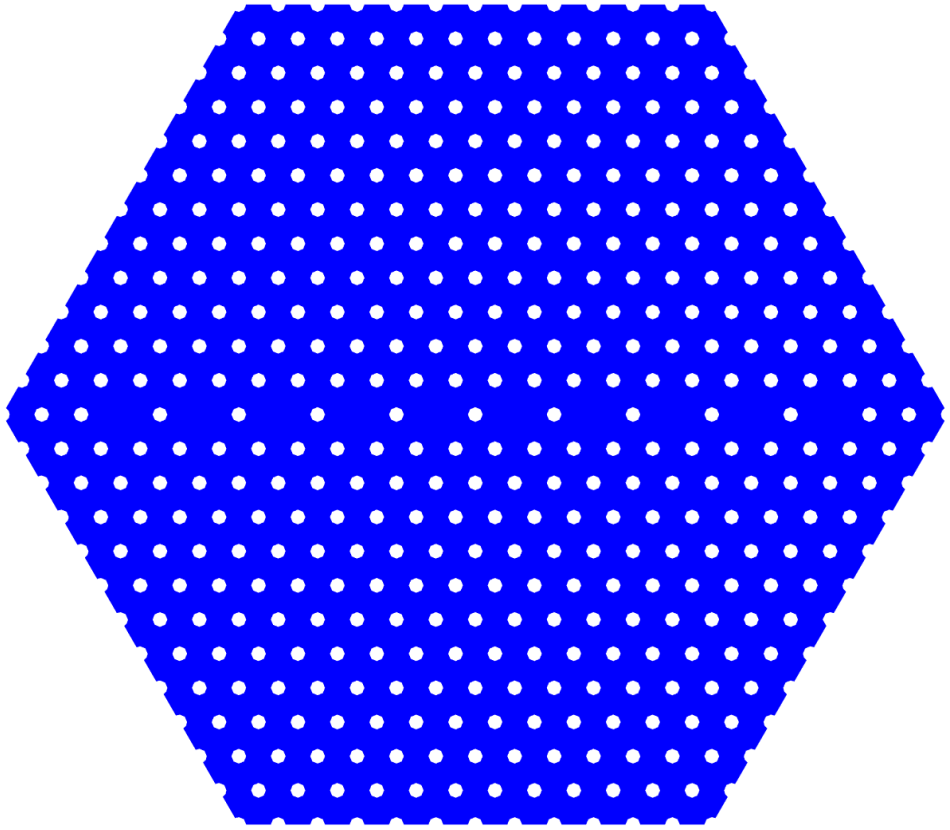
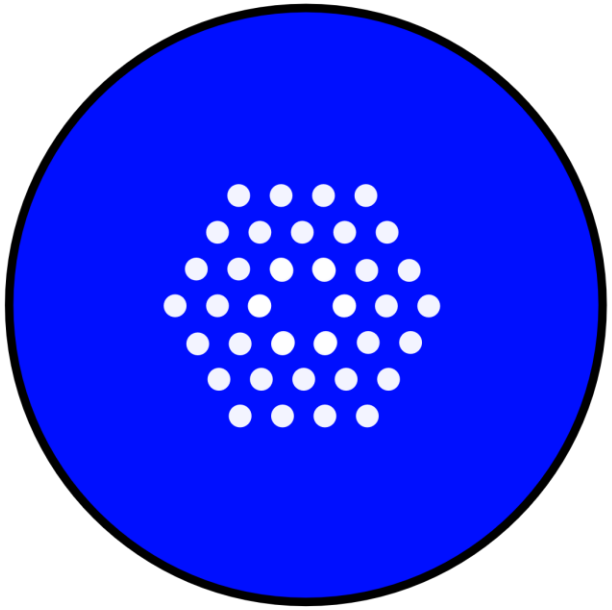
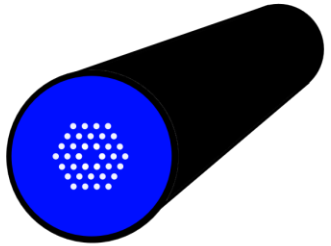
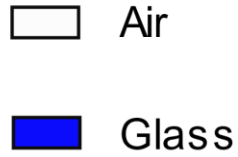
Non-Topological Fibre



Ten cores with uniform coupling







Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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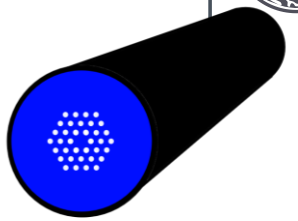
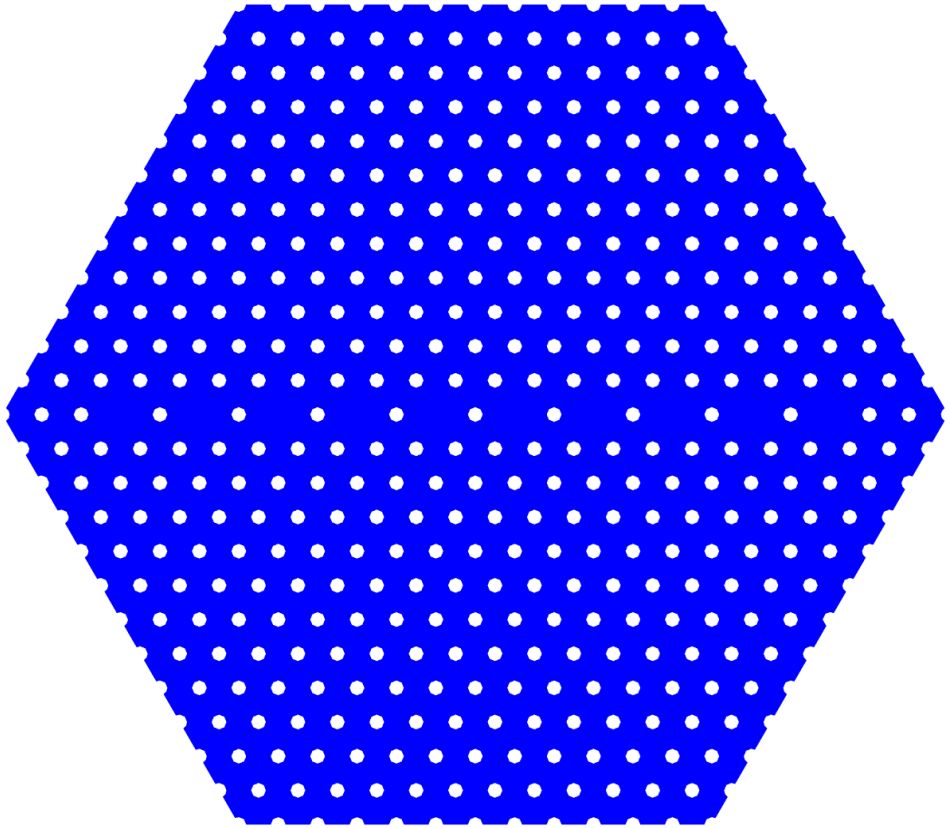
Non-Topological Fibre

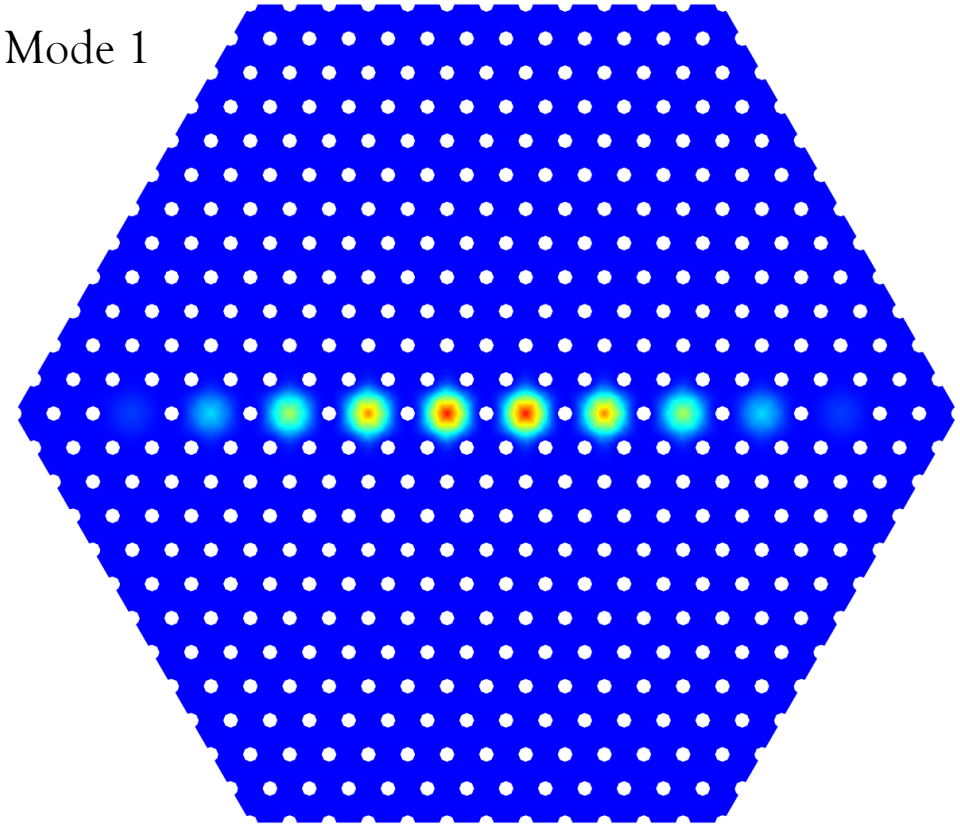


Air
Glass



Ten cores with uniform coupling

Mode 1



Each mode shows a distributed intensity profile

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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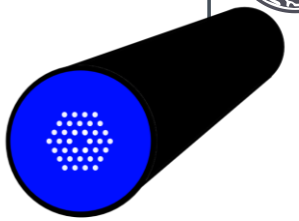
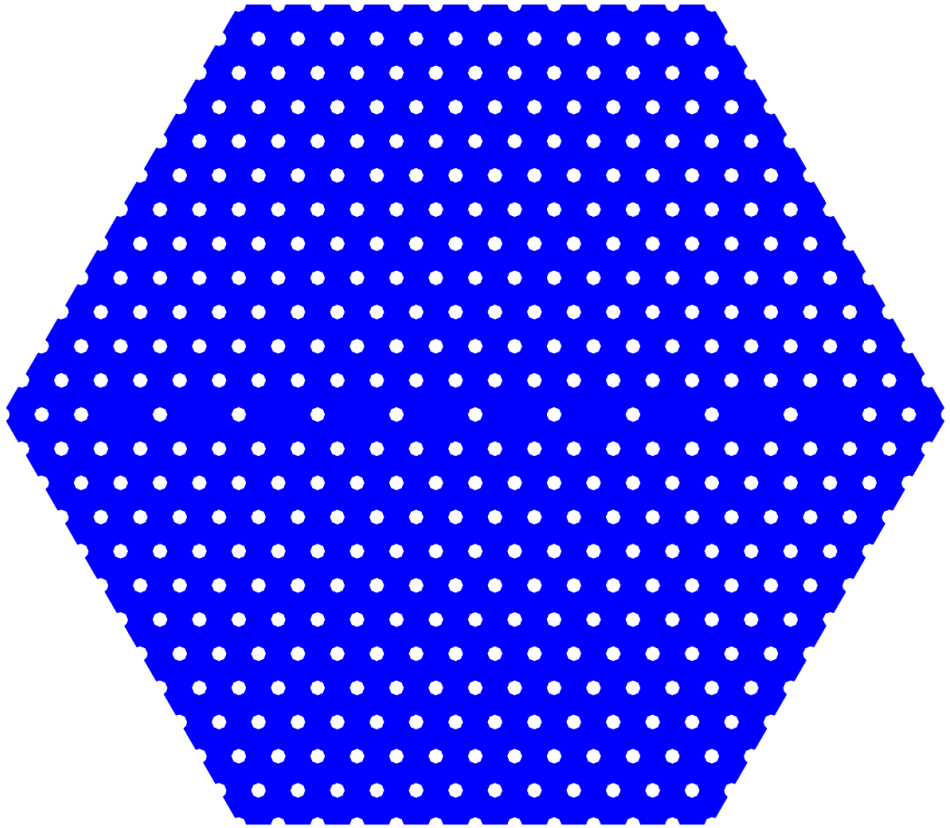
Air
Glass

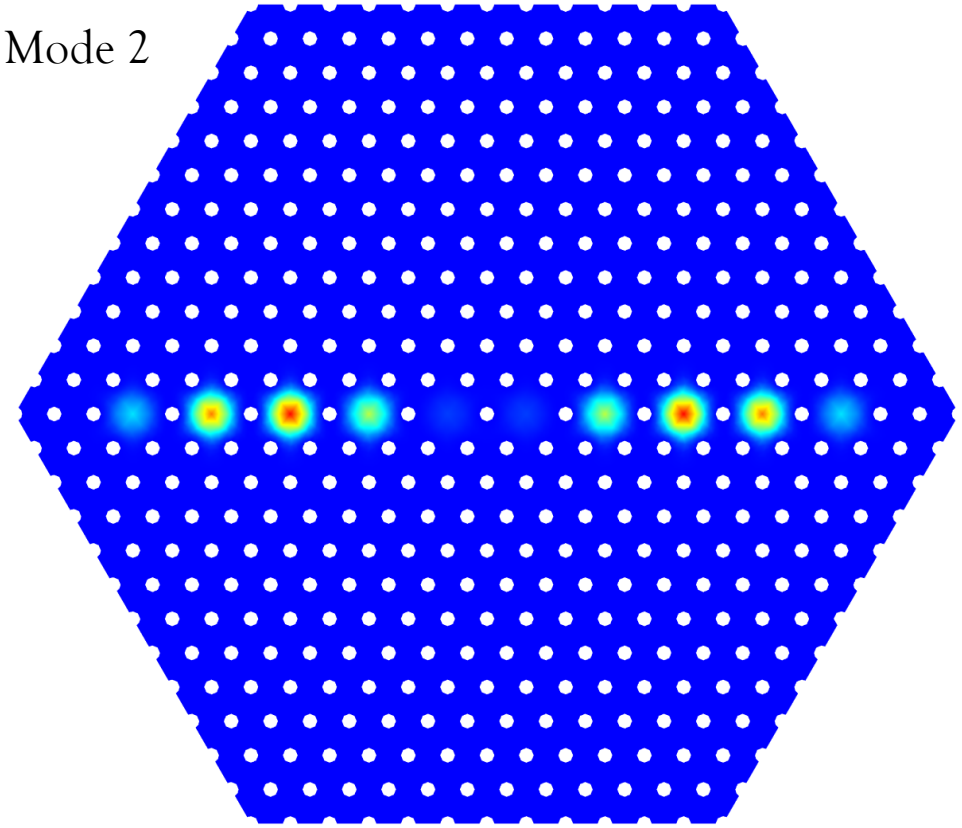
Non-Topological Fibre





Ten cores with uniform coupling

Mode 2



Each mode shows a distributed intensity profile

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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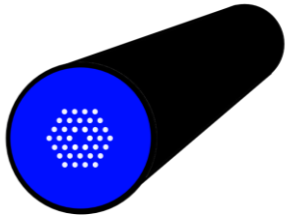
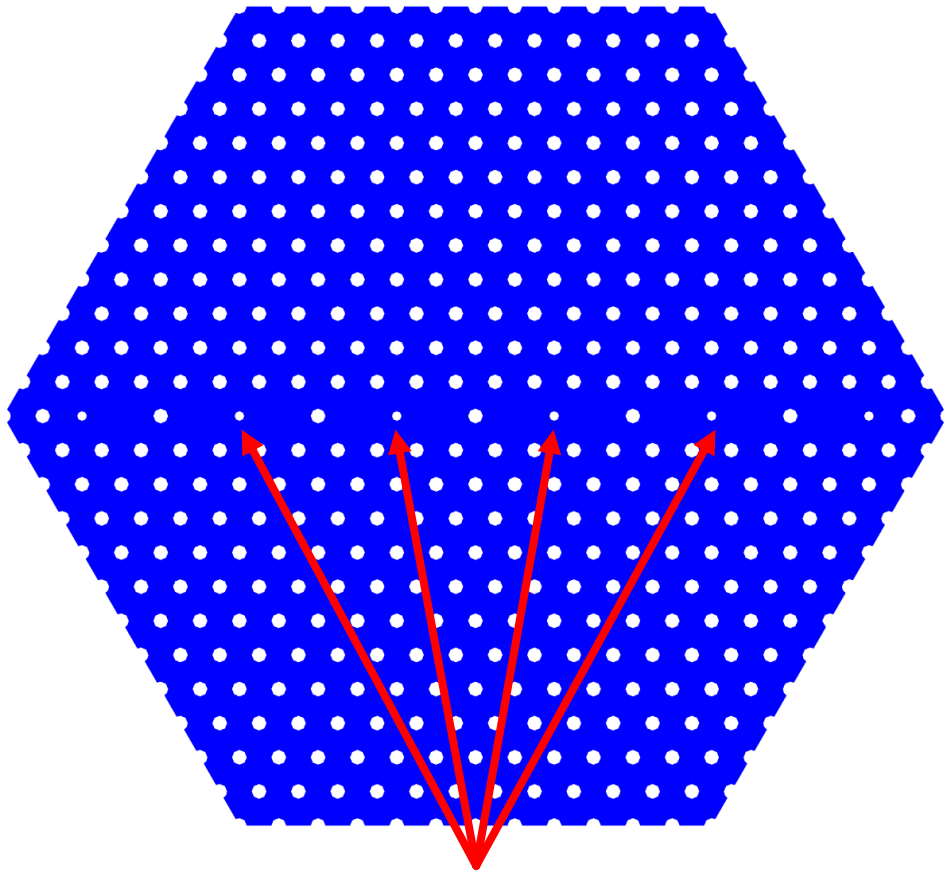
Topological Fibre





Air hole radius reduced to give increased coupling

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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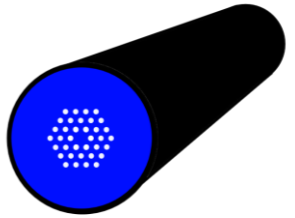
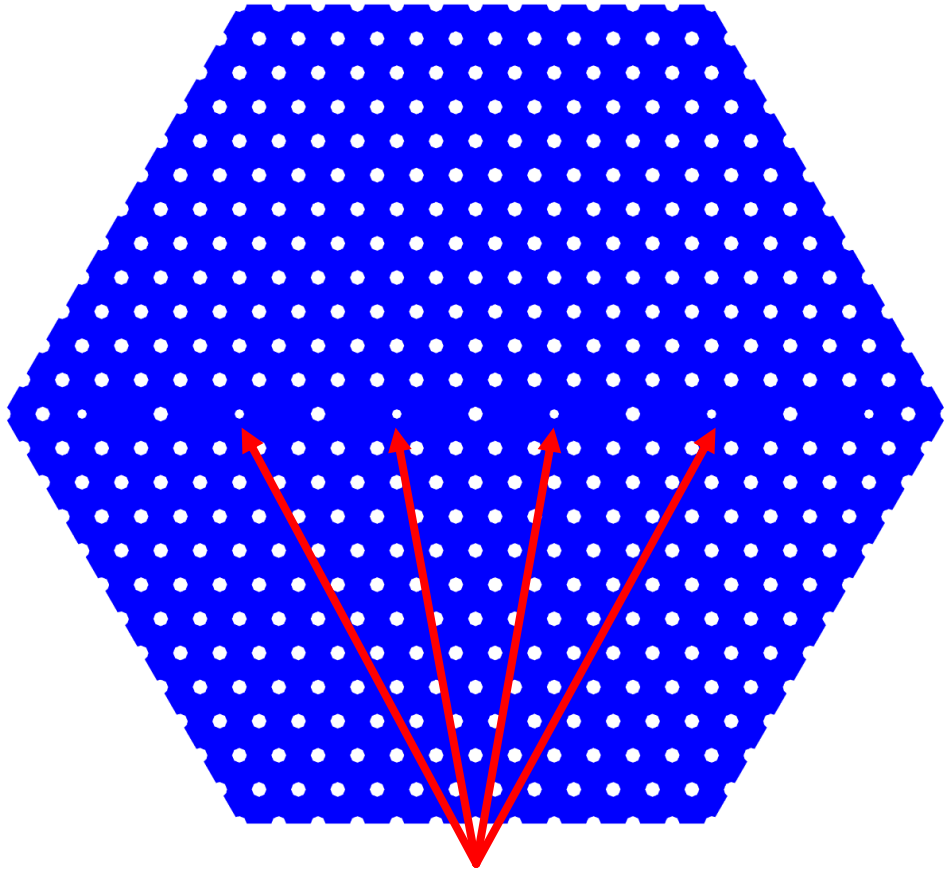
Topological Fibre

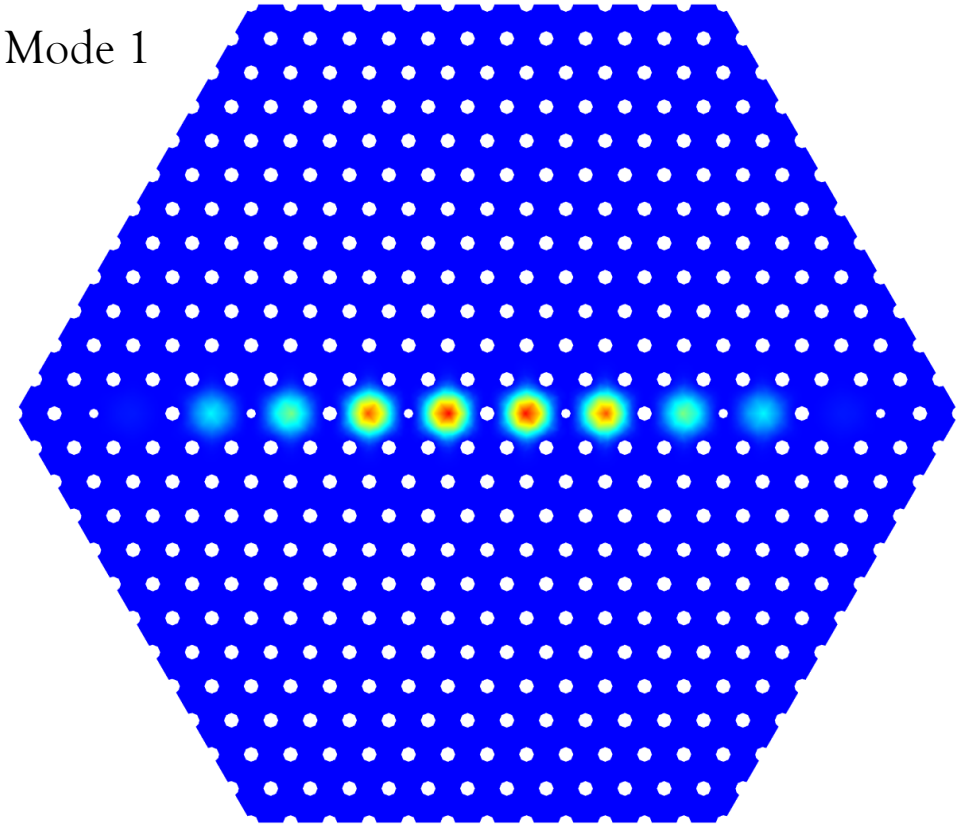


Air
Glass



Air hole radius reduced to give increased coupling

Mode 1



Eight modes show a distributed intensity profile

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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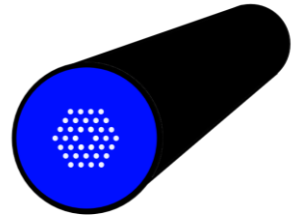
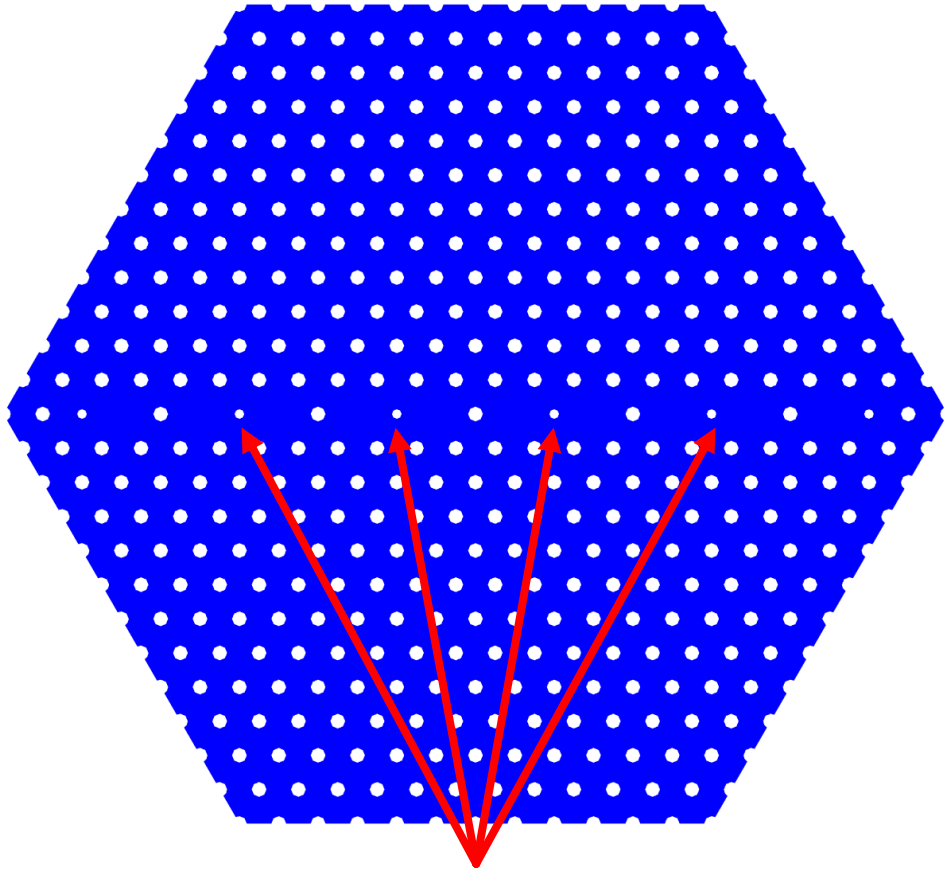
Topological Fibre

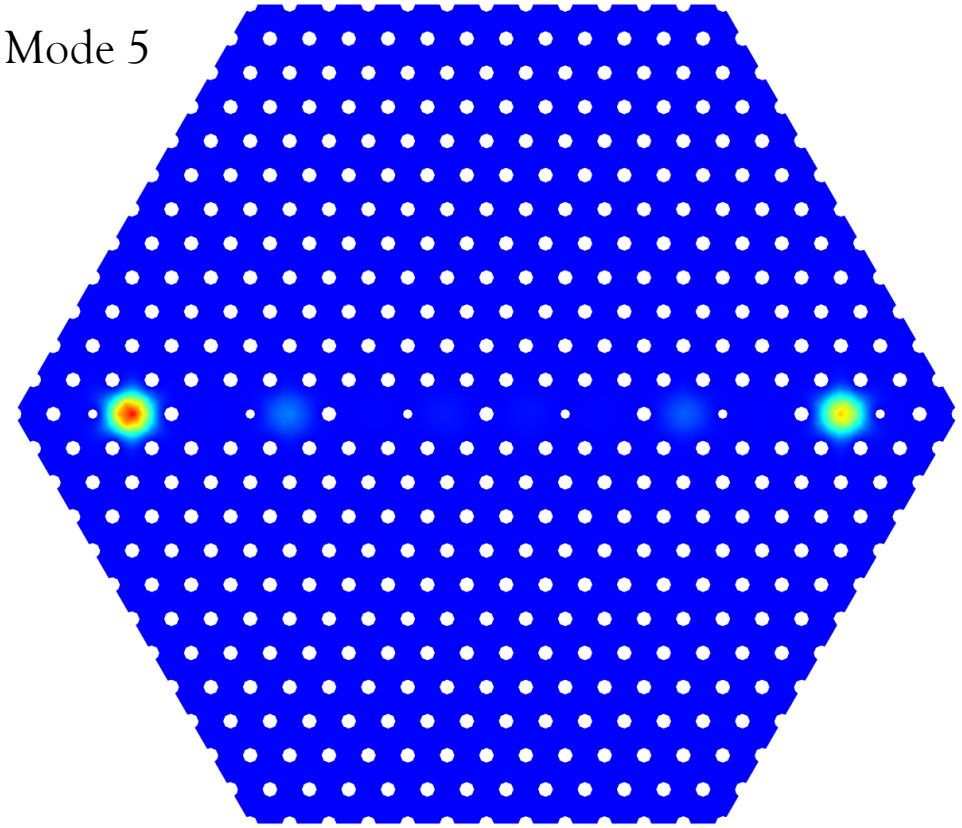


Air
Glass



Air hole radius reduced to give increased coupling

Mode 5



Two edge modes show a confined intensity profile

Roberts et al., *Sci. Adv.* 8 (2022),
Roberts et al., arXiv:2305.03630

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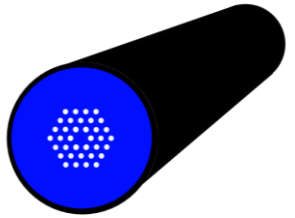
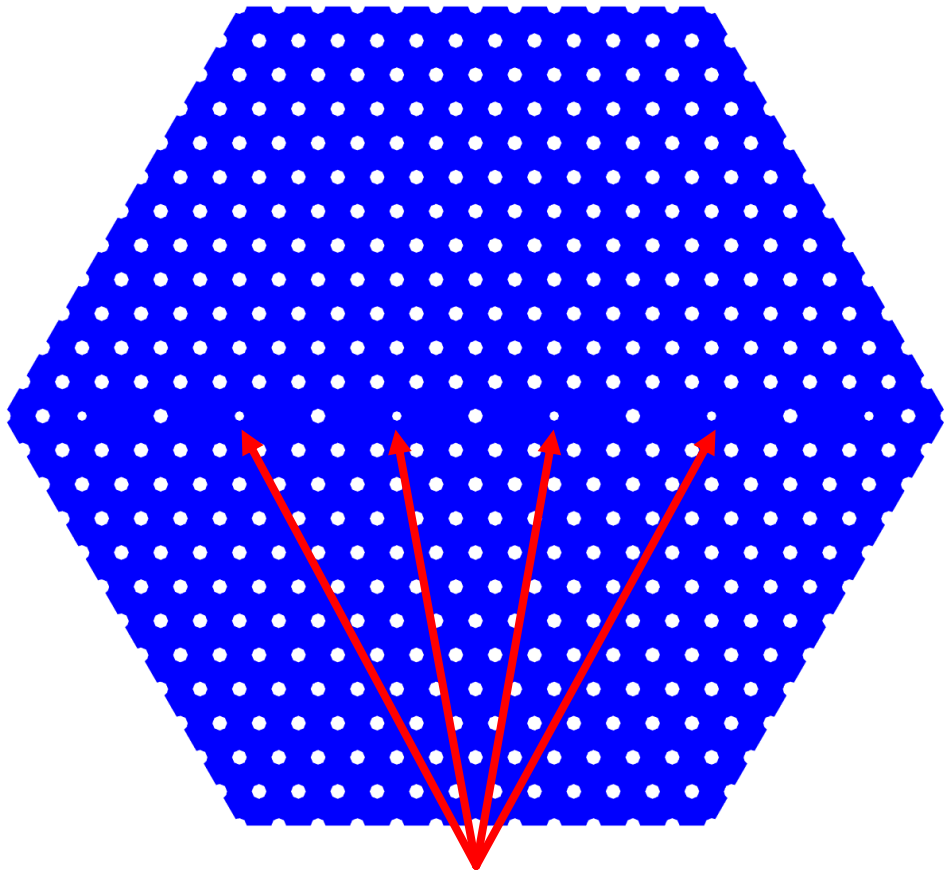
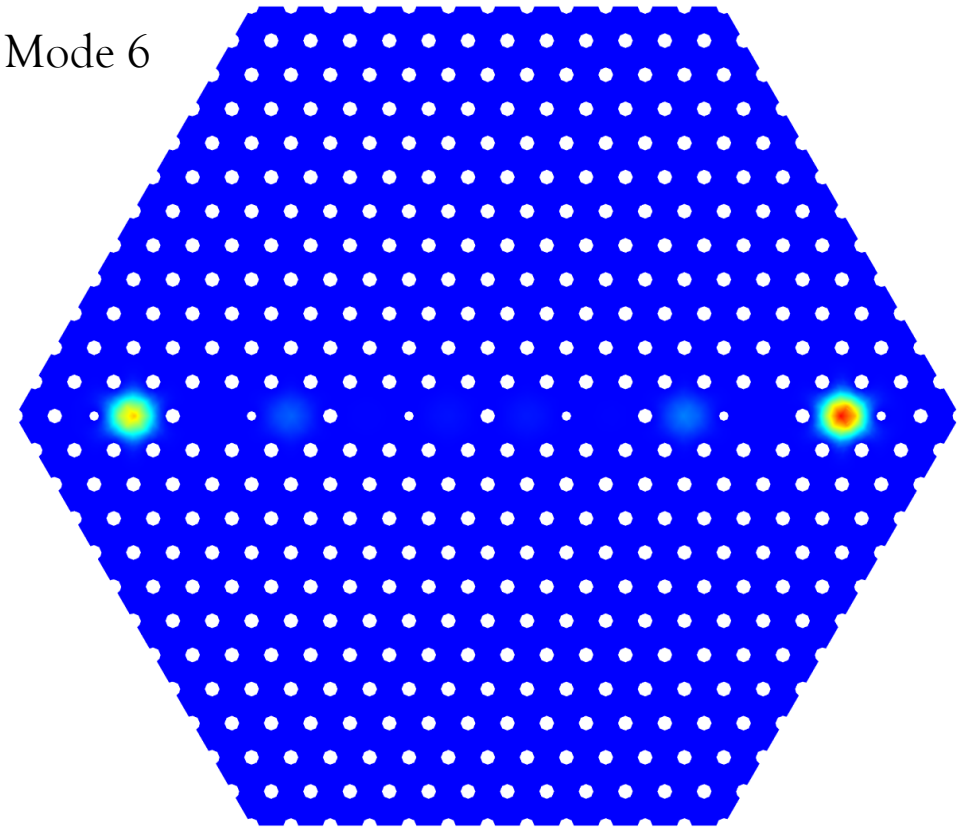
Topological Fibre





Air hole radius reduced to give increased coupling

Mode 6



Two edge modes show a confined intensity profile