Bending self-collimated one-way light in gyromagnetic photonic crystals by gradient magnetic field

Rui-Xin Wu

School of Electronic Sciences and Engineering

Nanjing University

Outline

- Background and Motivations
- Self collimated one-way light in magnetic photonic crystals
- Bending the self collimated one-way light by gradient magnetic field
- Possible applications
- Summary

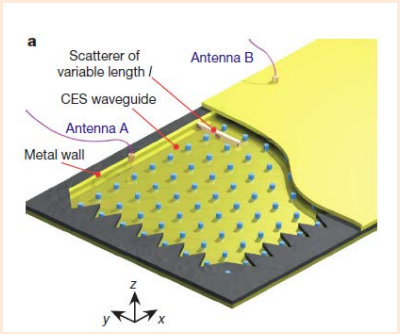
Background and Motivations

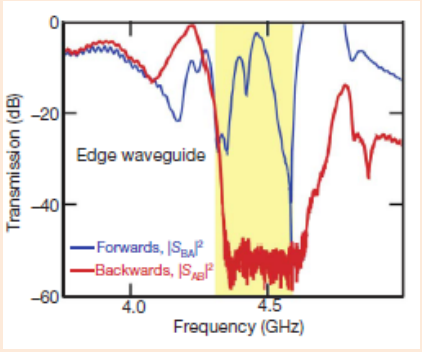
one-way wave is supported by two kind of modes

- Edge modes
- Bulk modes

- Edge mode

Chiral edge state, MPC, Ferrite

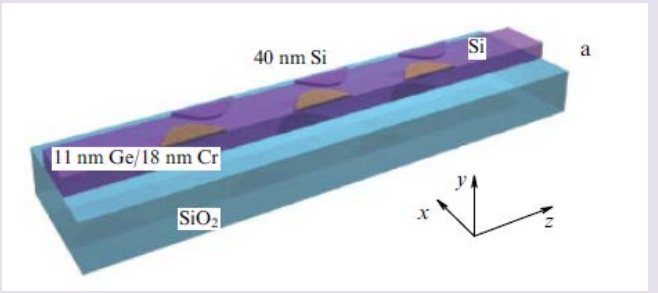


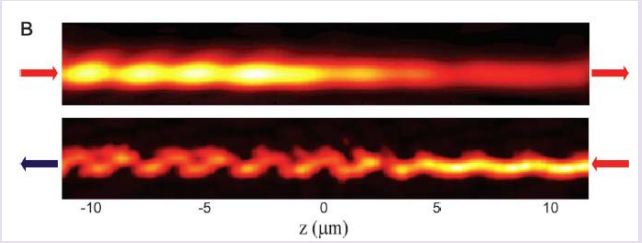


Z. Wang et al. Nature 461, 772(2009)

- Bulk mode

PT symmetry, loss-gain, Si

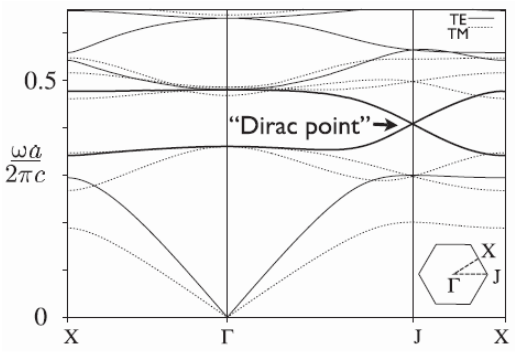




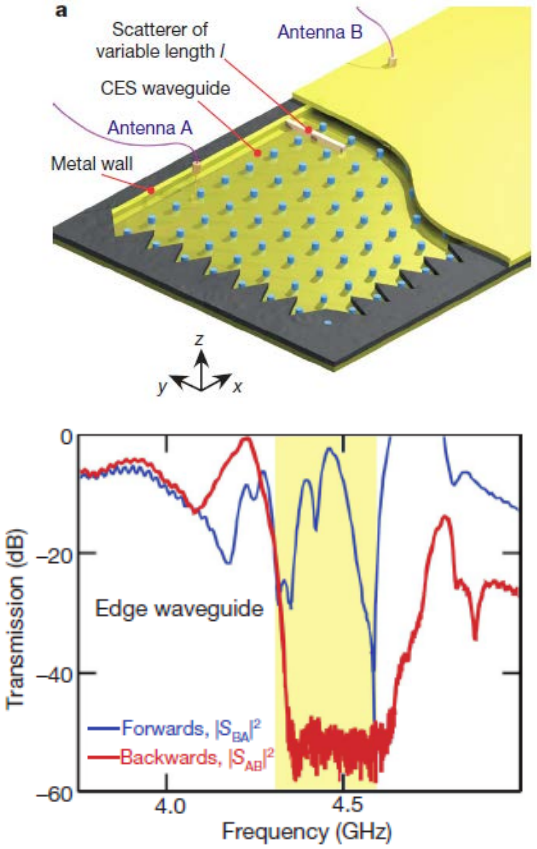
L. Feng, et al. Science 333 729 (2011)

Realization of one-way edge modes

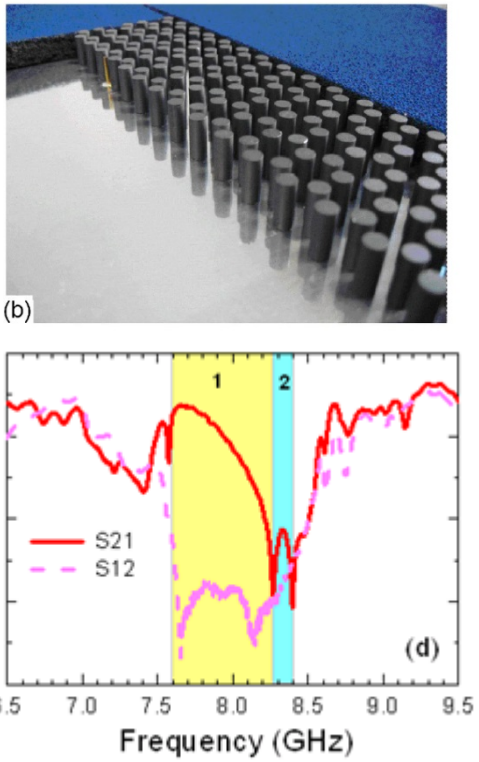
Chiral edge states



F.D.M.Haldane and S.Raghu, Phys. Rev. Lett. 100, 013904(2008)

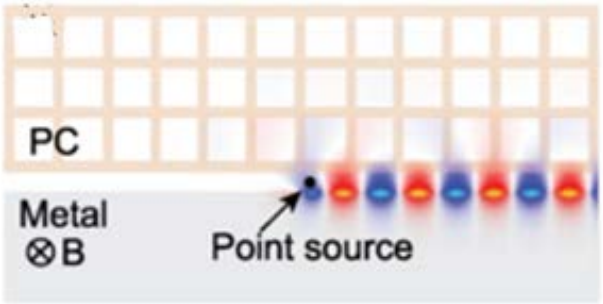


Z. Wang, et al. Nature 461, 772(2009)

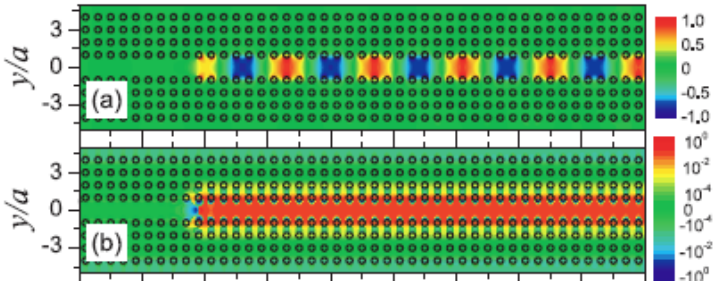


Y. Poo, et al., Phys. Rev. Lett. 106, 093903 (2011)

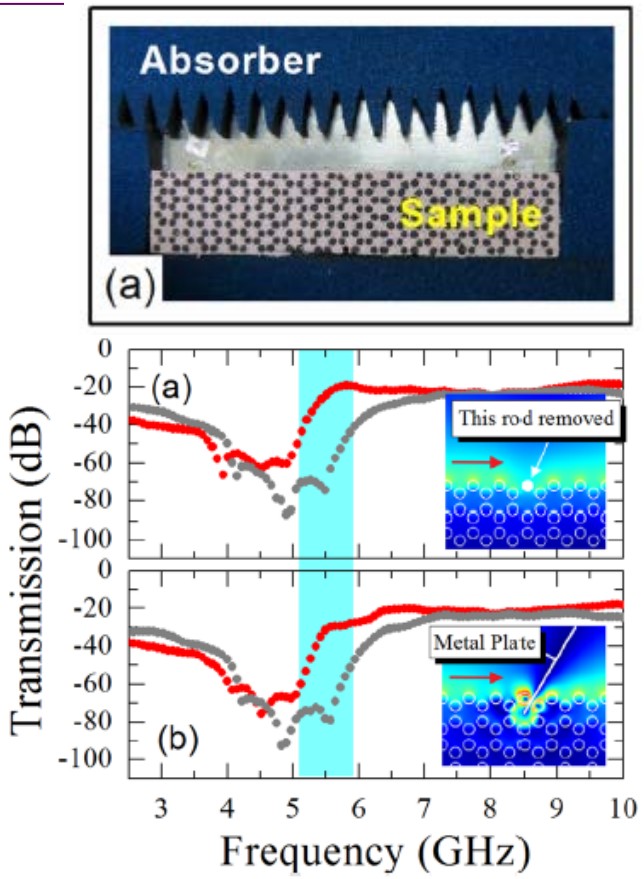
SPP at the support of magnetic field



Z. Yu et al. Phys. Rev. Lett. 100, 023902 (2008)

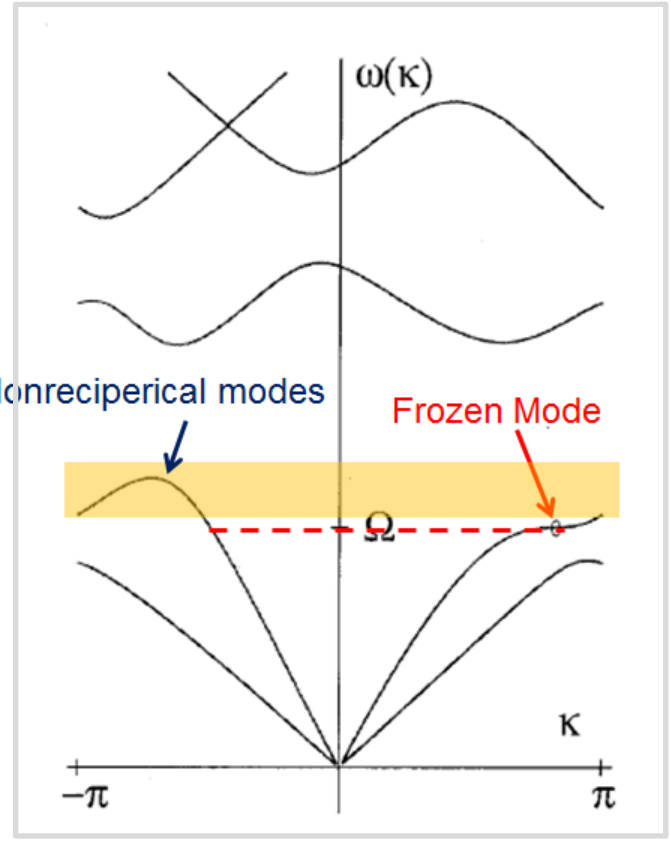


S.Y. Liu et al, Appl. Phys. Lett. 97, 201113 (2010)



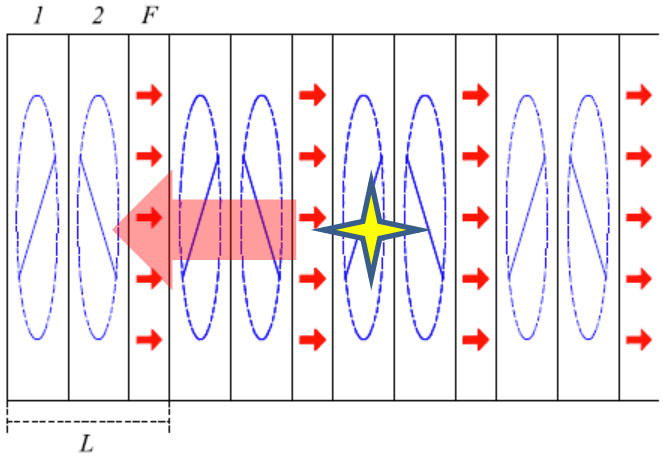
Y. Poo et al. Appl. Phys. Lett 101, 081912 (2012)

Realization of Non-reciprocal bulk modes

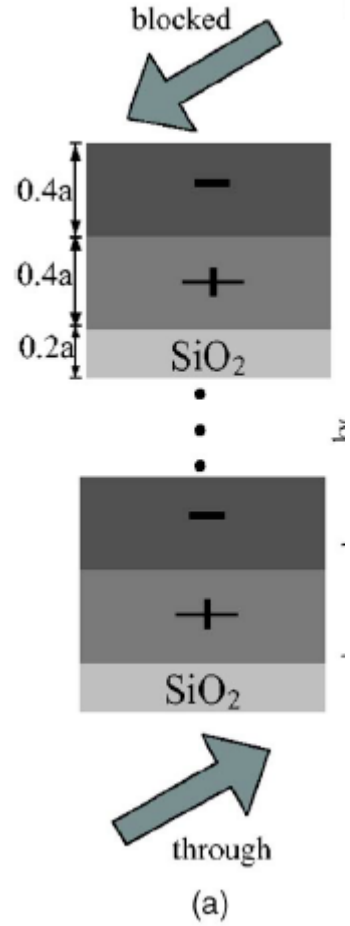


A. Figotin and I. Vitebsky, Phys. Rev. E 63, 066609 (2001)

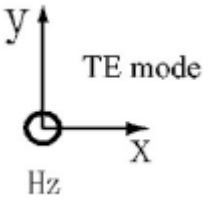
At nonreciprocal modes, wave goes in one direction

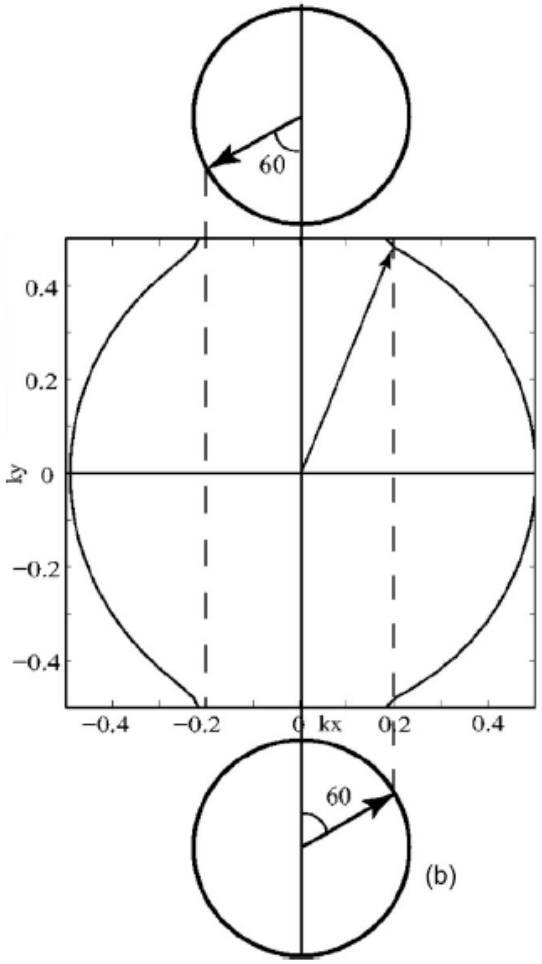


At frozen mode, wave goes in one directions because of in the other direction vg=0



Bismuth iron garnet (BIG)

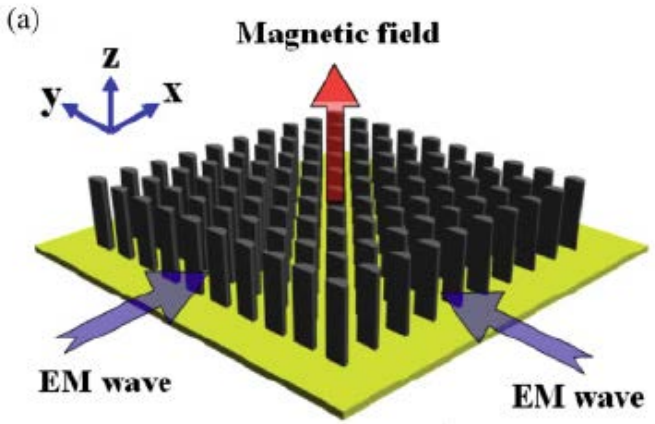


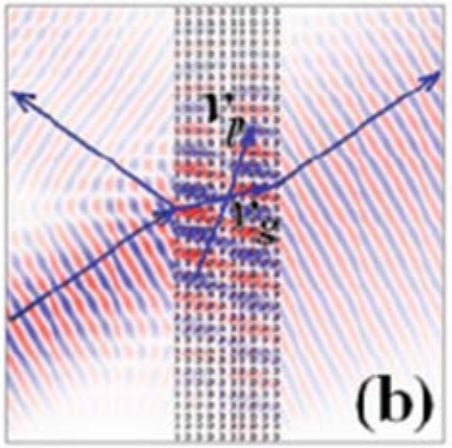


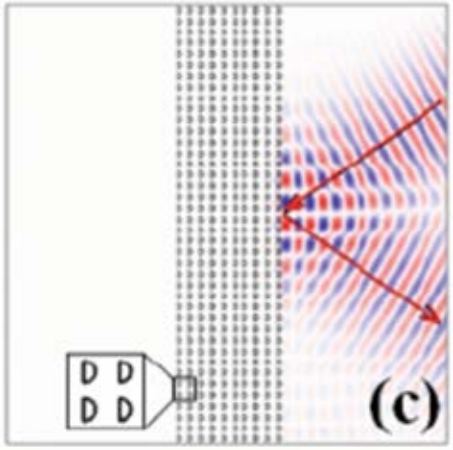
Each primitive cell consists of two high-index BIG layers, with opposite magnetic directions along *z* directions, and a low-index SiO2 layer

Zongfu Yu, et al, Applied Physics Letters 90, 121133 (2007)

2D Magnetic Photonic Crystals





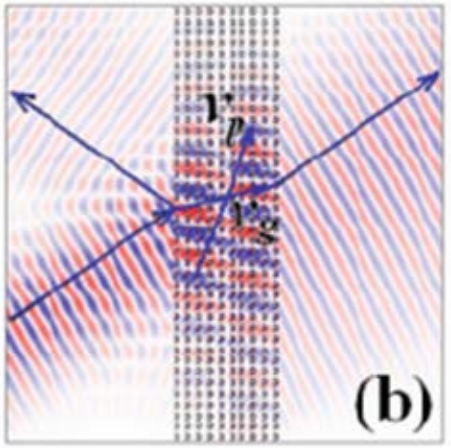


Cheng He, et al, Physical Review B 83, 075117 (2011)

- **Motivation**

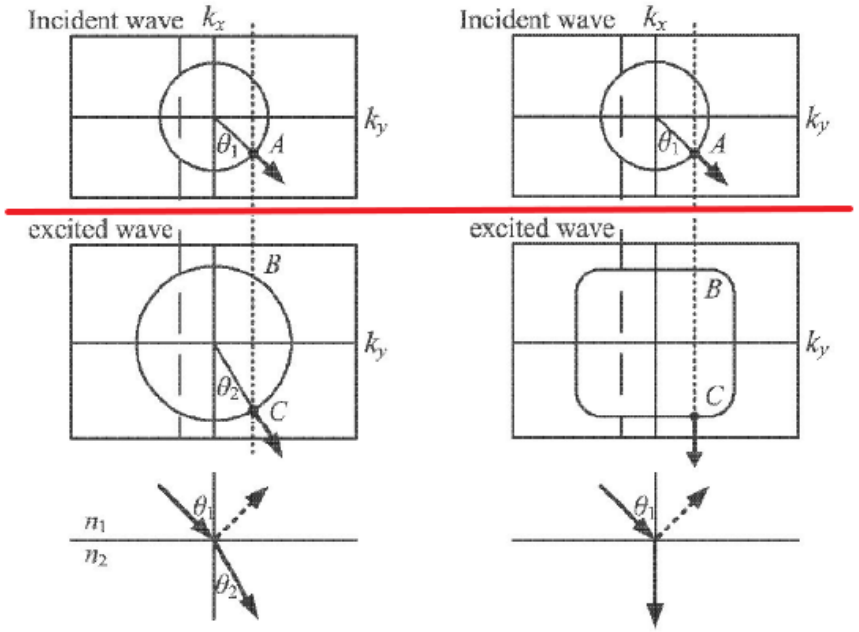
  ? How to use one-way bulk modes to control the wave beam propagation in PC?

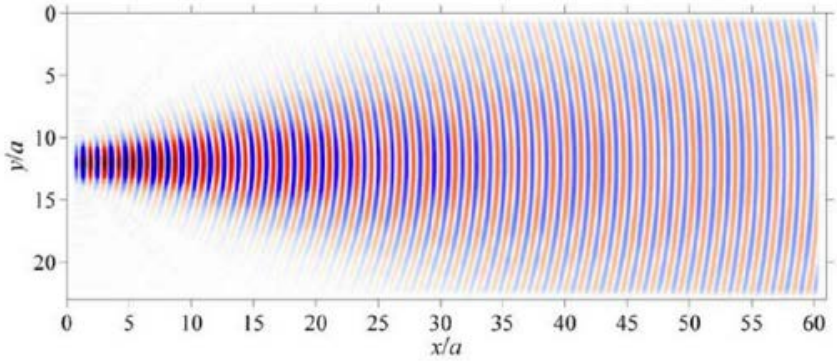
  ? Is there any potential applications of one-way wave beam ?



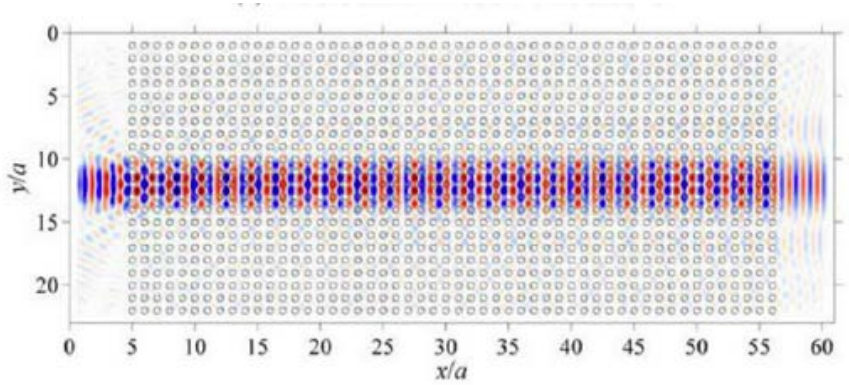
- **Our method:**

  Self-collimated one-way wave beam

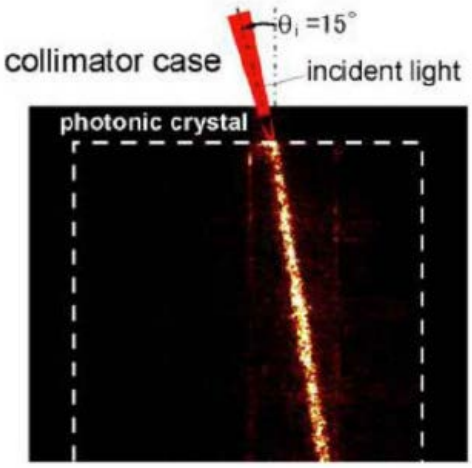




Gaussian bean in Si slab

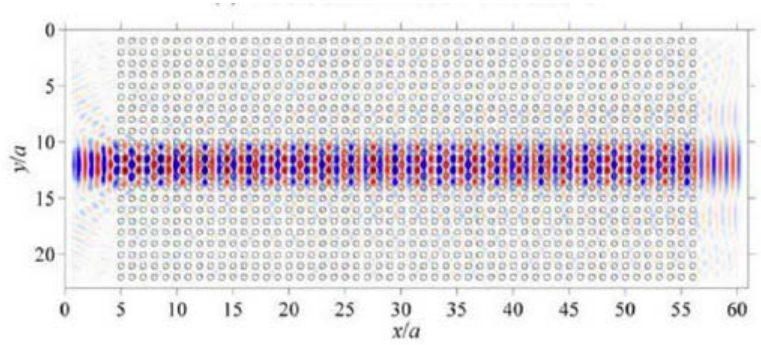


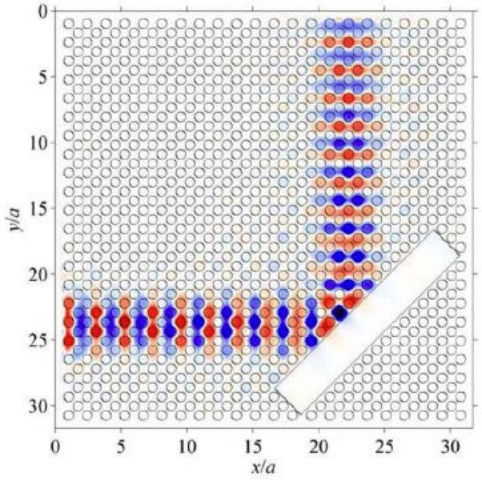
Gaussian bean in PC



H. Kosaka, et al, Appl. Phys. Lett. 74, 1212-1214 (1999)

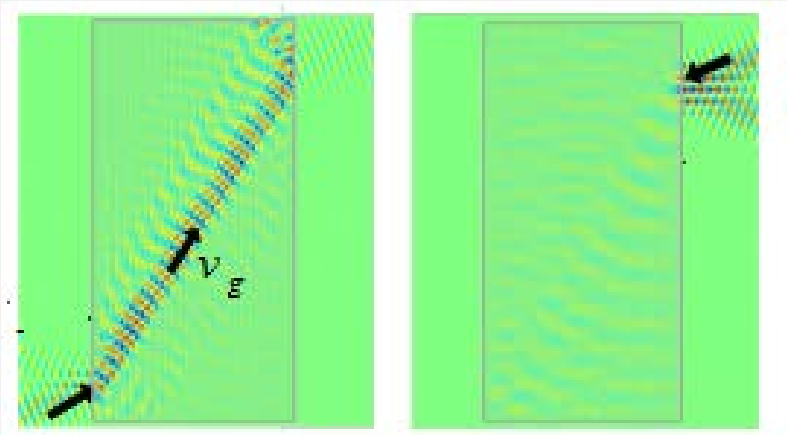
PC

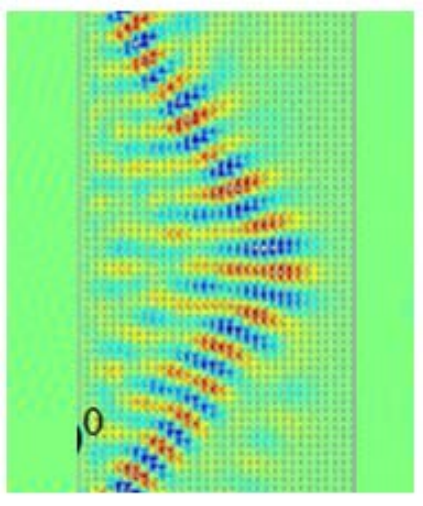




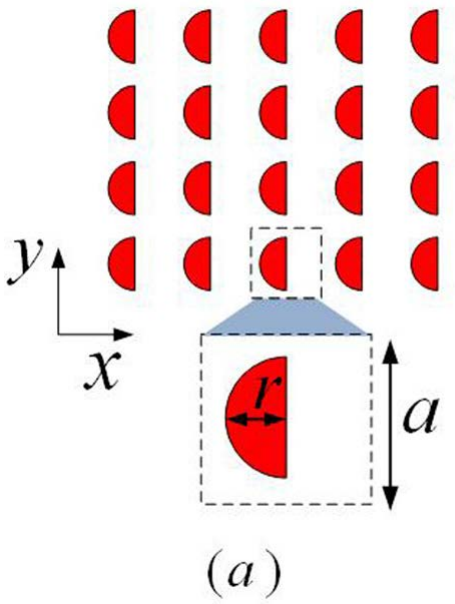
? One-way wave beam

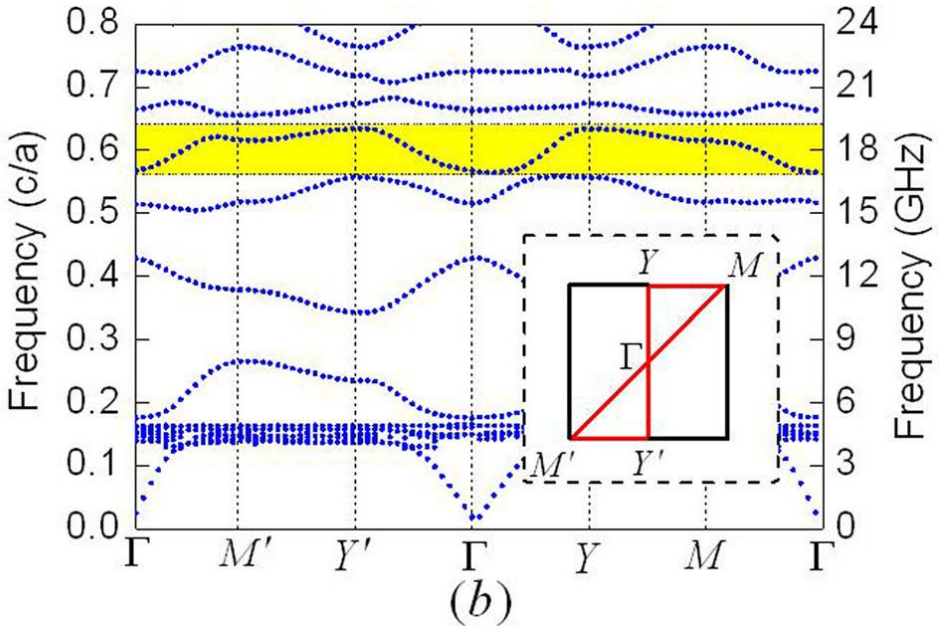
? Tunable wave beam direction





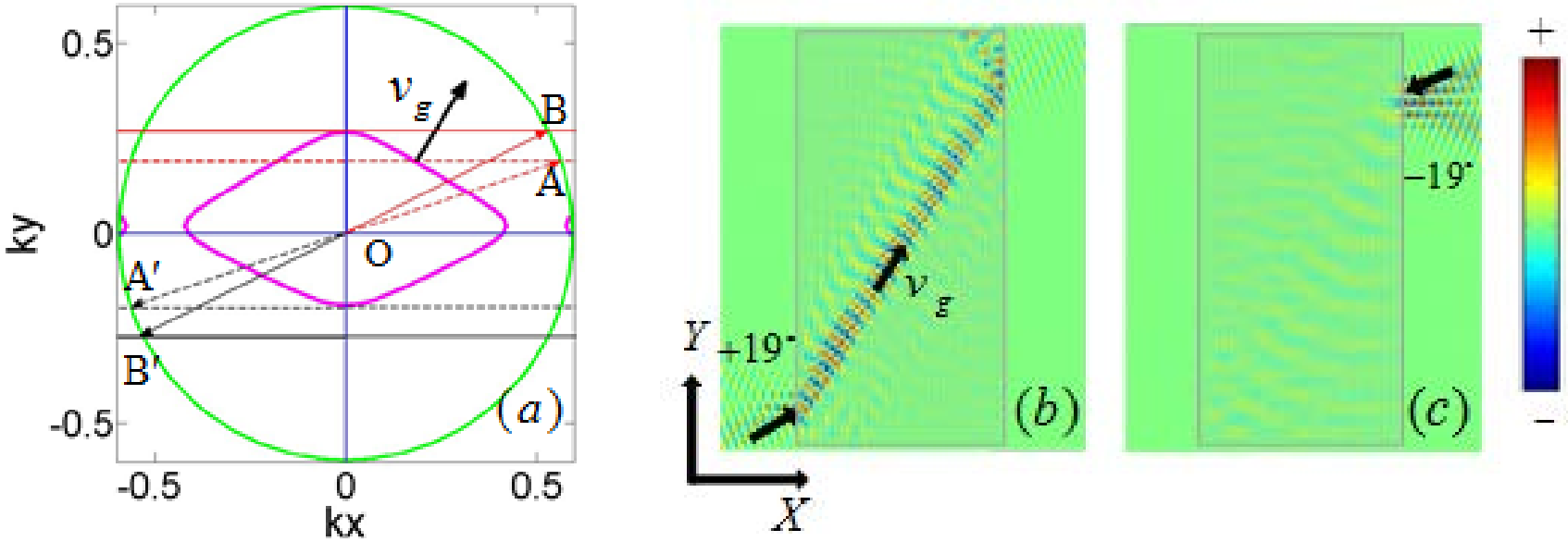
Self collimated one-way light in magnetic photonic crystals





MPC consists of YIG rods .

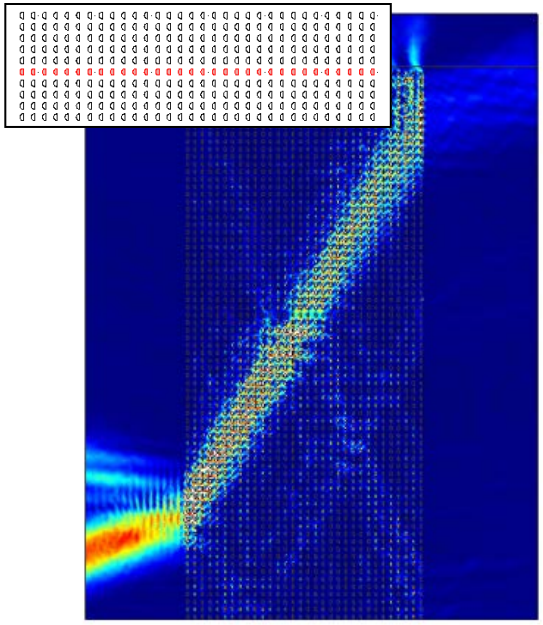
@17.8 GHz



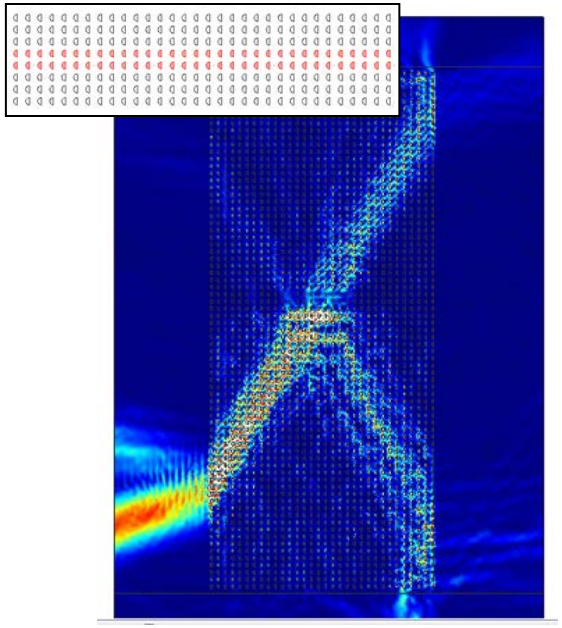
Between the incident angle 19°-27°, the transmitted waves are non-reciprocal in opposite directions

Robustness of wave beam transmission

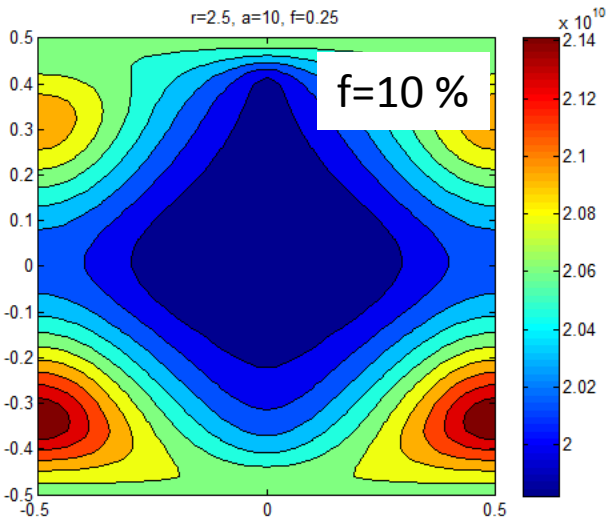
One line rods removed

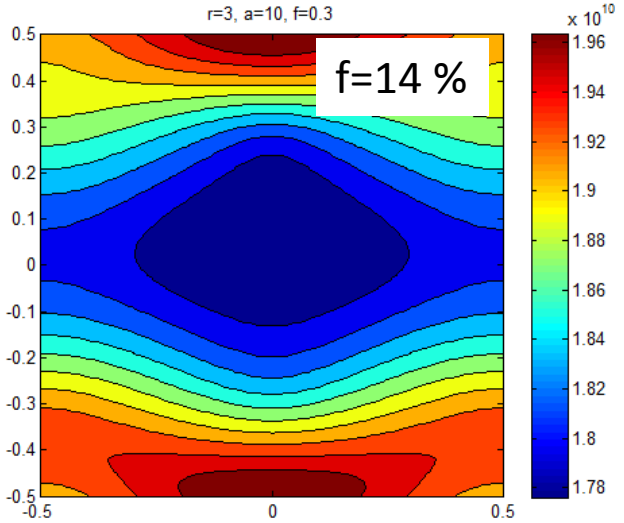


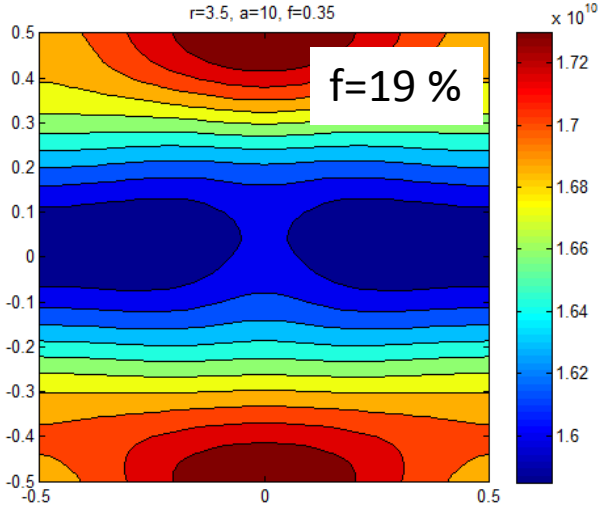
two line rods removed

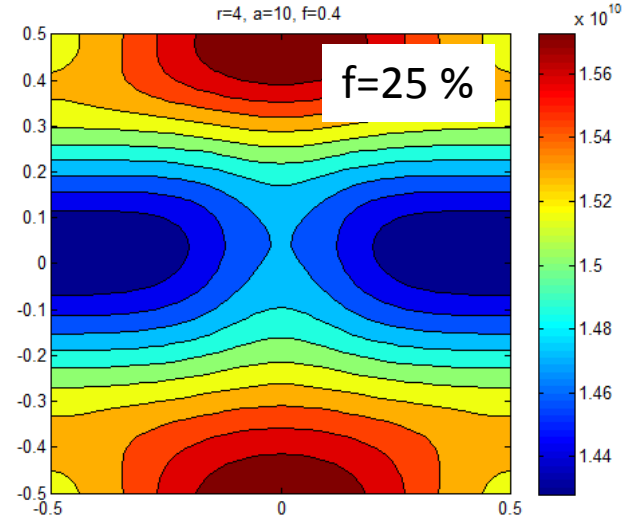


The self-collimated one-way wave shows robustness on some level for some kind of defects


r=2.5, a=10, f=0.25
f=10 %
x 10^10
2.14
2.12
2.1
2.08
2.06
2.04
2.02
2
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5

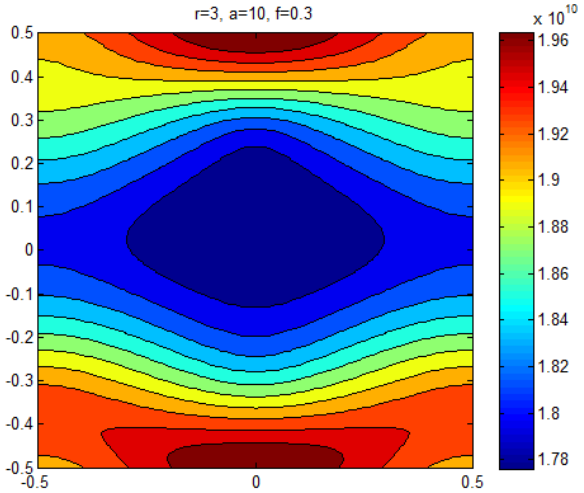

r=3, a=10, f=0.3
f=14 %
x 10^10
1.96
1.94
1.92
1.9
1.88
1.86
1.84
1.82
1.8
1.78
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5


r=3.5, a=10, f=0.35
f=19 %
x 10^10
1.72
1.7
1.68
1.66
1.64
1.62
1.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5

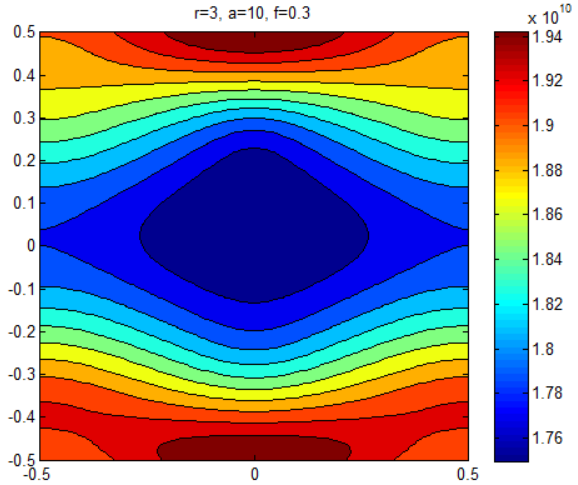

r=4, a=10, f=0.4
f=25 %
x 10^10
1.56
1.54
1.52
1.5
1.48
1.46
1.44
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.5
0
0.5

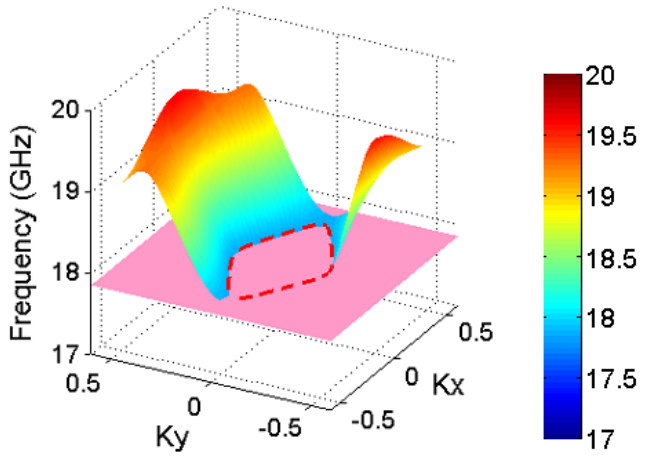
Bias magnetic field alters the area bounded by the EFCs.

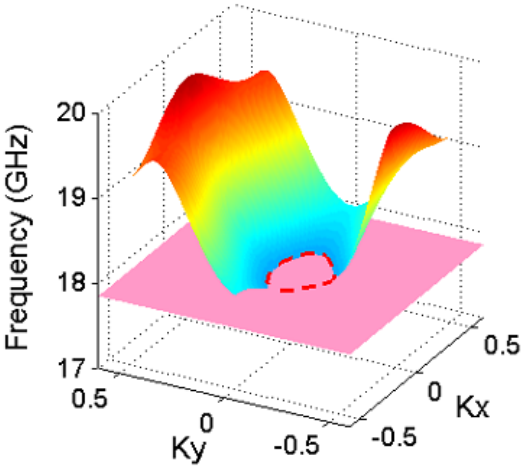
H=1000 Oe



H=1600 Oe

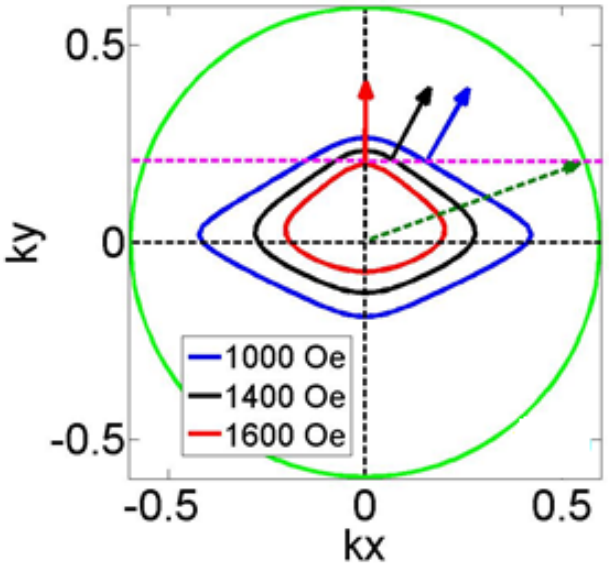


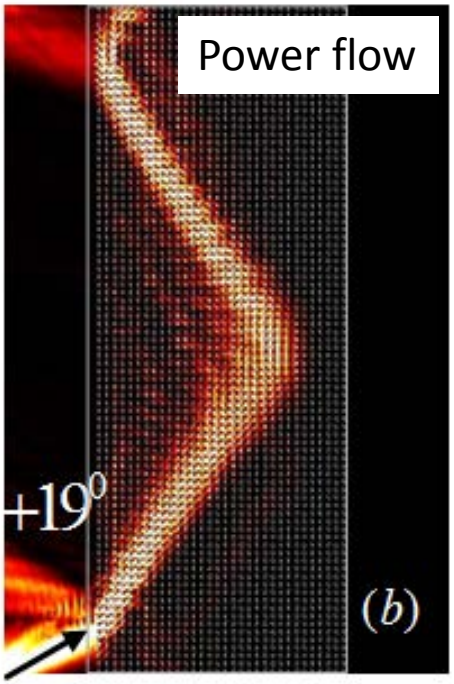




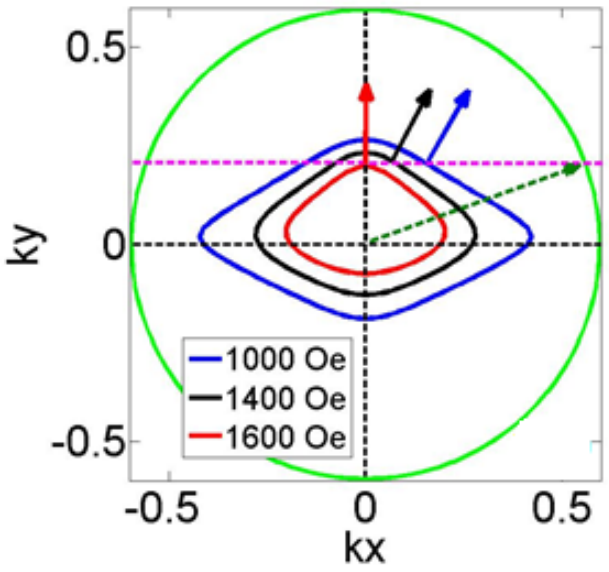
The bias magnetic field changes the value of the energy band but not its shape

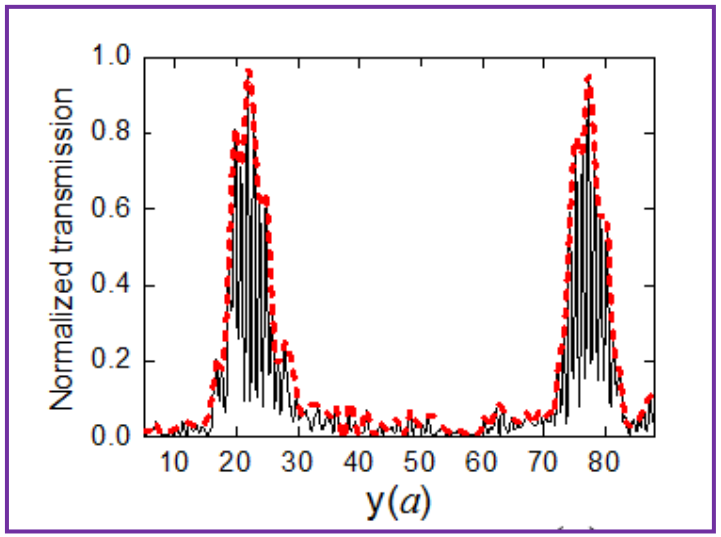
Bending the self collimated one-way light by gradient magnetic field

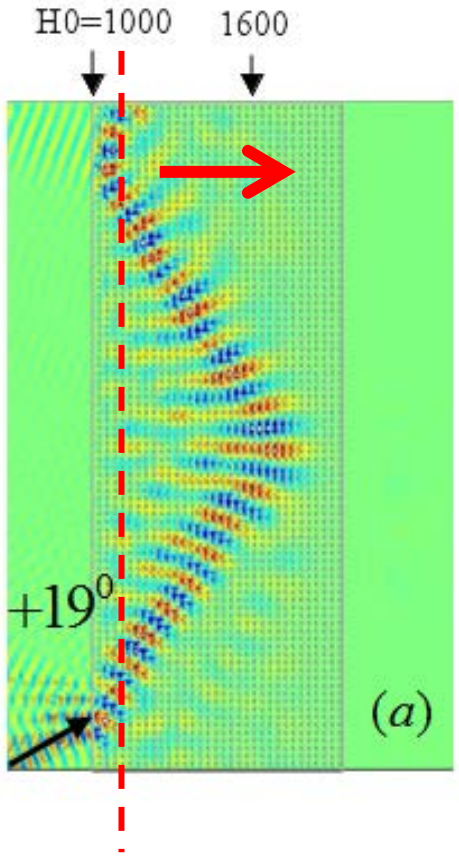


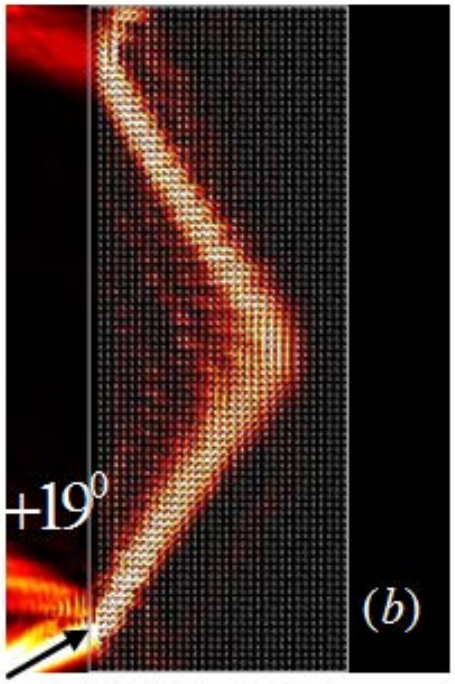


At constant incident angle and working frequency, the direction of refracted wave changes with magnitude of the bias magnetic field





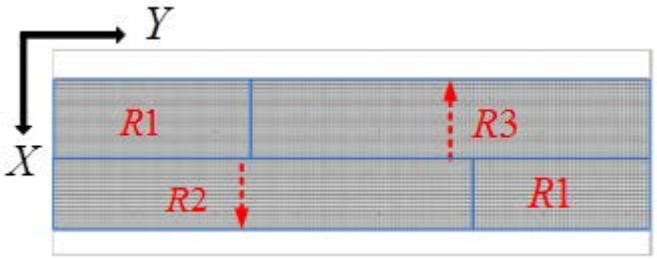




Bending loss is small

More bending of the wave beam:

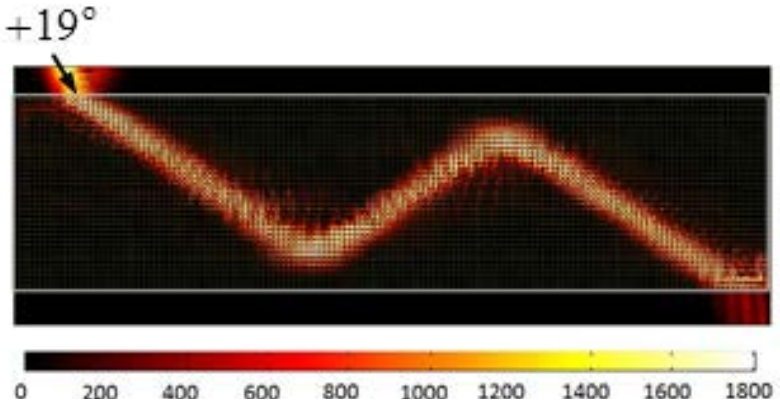
Depend on the bias magnetic field distribution

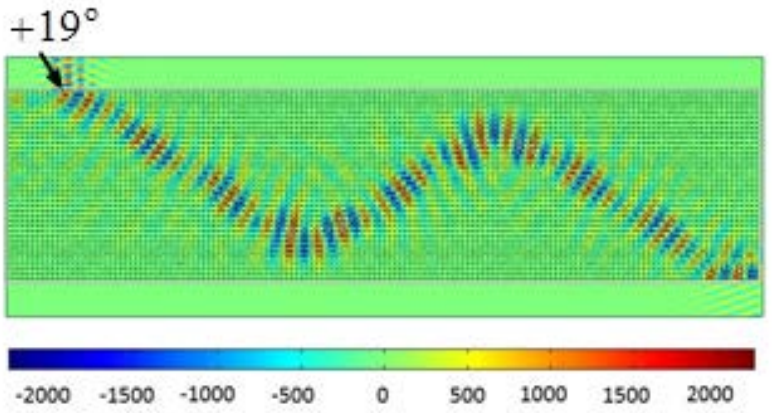


R1: uniformly biased, H0=1000 Oe

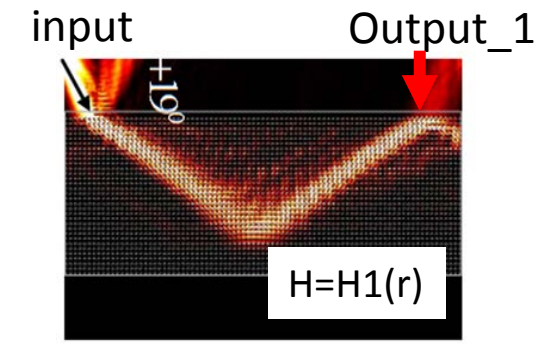
R2: biased by a gradient magnetic field ΔH=35 Oe/rod

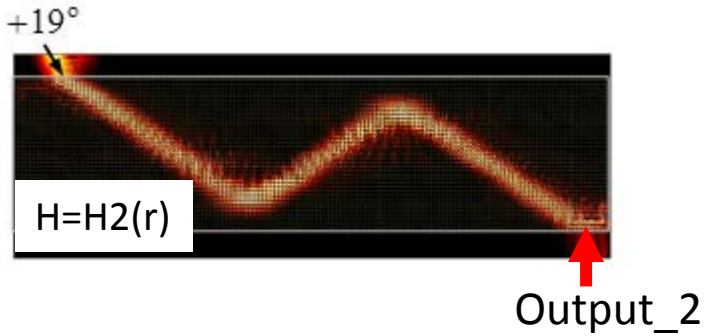
R3: same as R2, opposite gradient direction.





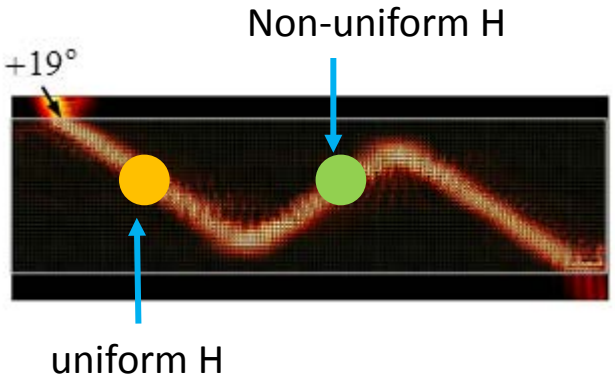
Applications





In dynamic bias magnetic configuration MPC functions as:

1. one input and multiple outputs "EM diode"
2. Switches
3. Tunable connector In optic circuits



Summary

- Self-collimated one-way wave is demonstrated in gyromagnetic photonic crystals with PT symmetry.
- One-way light beam can be steered in different directions by gradient magnetic fields
- The ability to steer one-way light beams could have a variety of applications in optical circuits.

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Thank You ！