Broadband graphene polarizer

Qiaoliang Bao, Han Zhang, Bing Wang, Zhenhua Ni, Candy Haley Yi Xuan Lim, Yu Wang, Ding Yuan Tang and Kian Ping Loh

Department of Chemistry, National University of Singapore
School of Electrical and Electronic Engineering, Nanyang Technological University,
Institute of Materials Research and Engineering, Agency for Science, Technology and Research, Singapore

Department of Physics, Southeast University, Nanjing, China

Service OPERA-photonique, Universite´ libre de Bruxelles, Belgium

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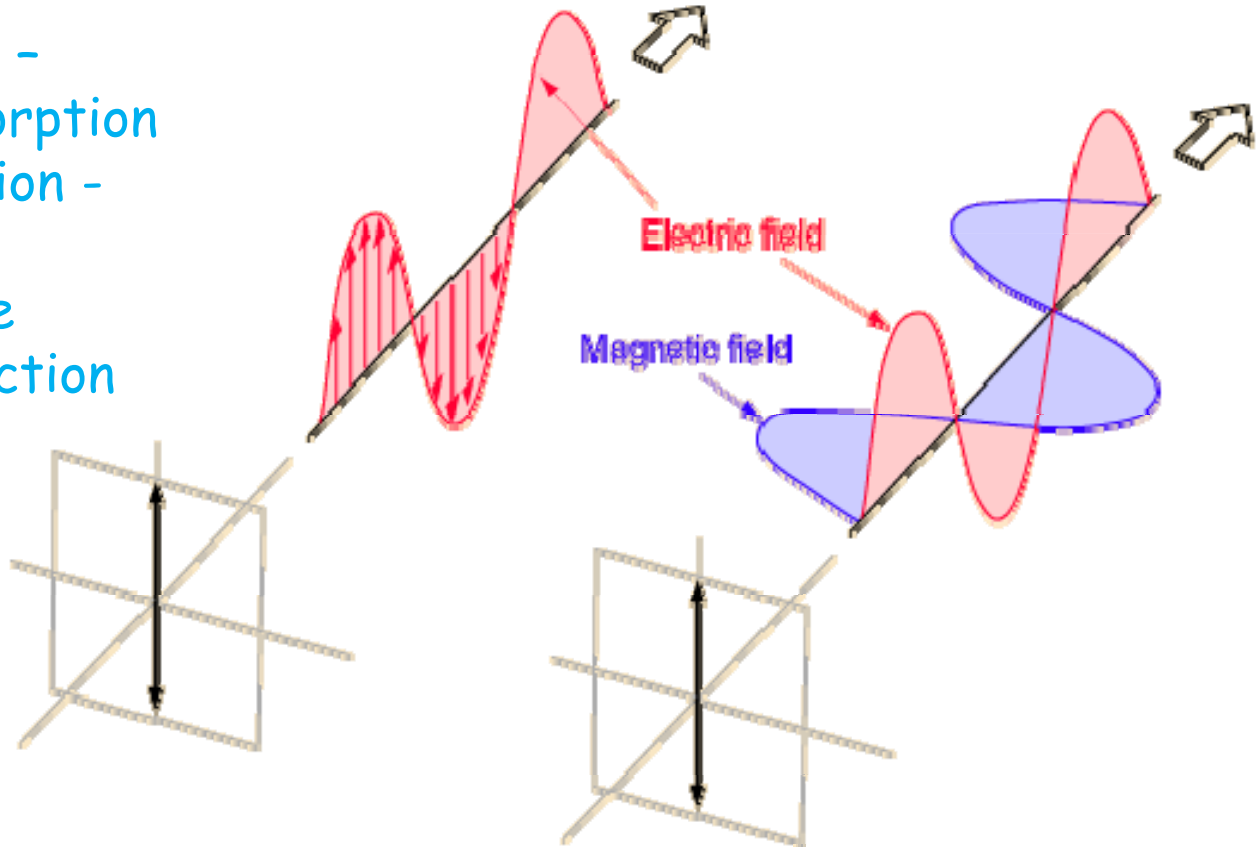
- Introduce Light (EBC)
- Introduce Polarization
- conventional polarizers

1. sheet polarizer – anisotropic absorption
2. prism polarization - refraction
3. Brewster's angle polarizer- reflection



Back ground of the work

- conventional polarizing components are not easily fit into photonic circuits

- In-line fibre polarizer (polarization selective coupling between the evanescent field and birefringent crystal or metal) –compatibility with fibre optics systems

Graphene???

- Remarkable electronic and optical properties

- excellent transport property

- Optical conductivity – defines by fine structure constant – independent of λ

- Zero band gap affords the high band width detection of light

- it is a saturable absorber – (broad band, ultra fast mode-locked lasers for use in tele communication)

- 2D nature allows the fabrication of photonic circuits with ultra thin optical elements – (graphene- router, modulation or detection of light)

- Ability to couple and modulate light with such an ultra thin guiding material is yet to be demonstrated

Present work

- coupling guiding and polarizing of electromagnetic waves by graphene

- The polarization mechanism is attributed to differential attenuation of two polarizing modes

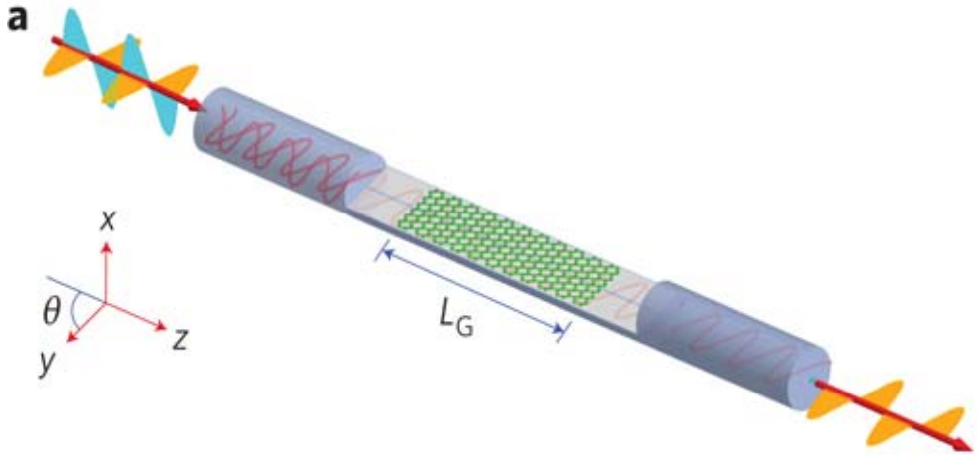
- $\sigma(\omega) = in_s e^2 / m(\omega + i\tau)$ Drude model- positive imaginary part – TM mode

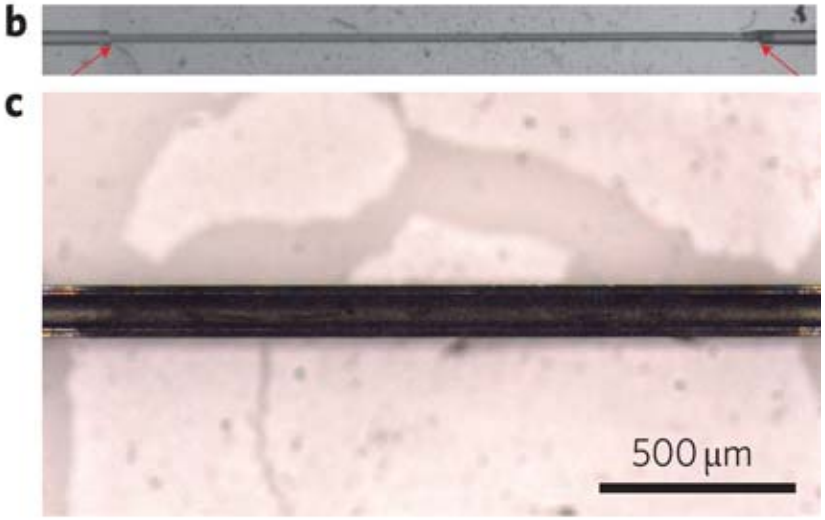
- TE mode is forbidden at a single interface between a metal and a dielectric – mass dependane

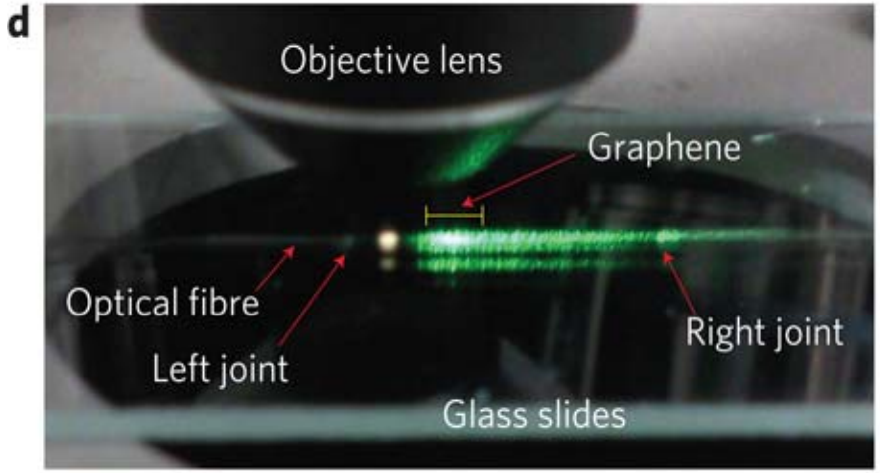
- In graphene optical conductivity is different – presence of massless Dirac fermions (TM)

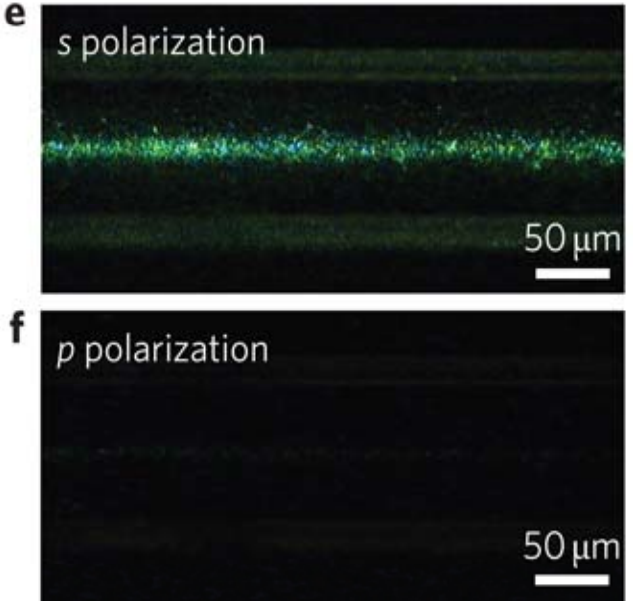
- Intra band transitions give rise to a Drude like behaviour; inter band optical transitions gives rise to a negative imaginary part (TE mode)- weakly damped mode propagating with almost C

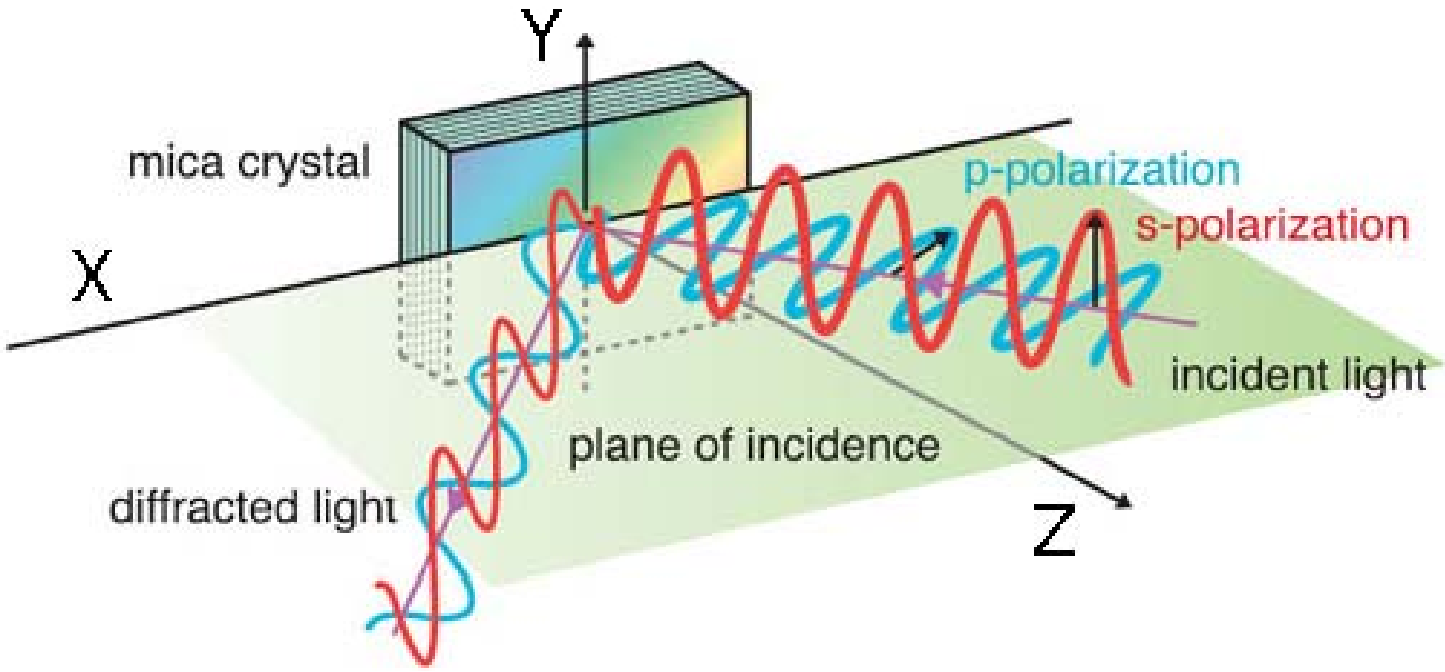
15 mm


a
x
θ
z
y
L_G

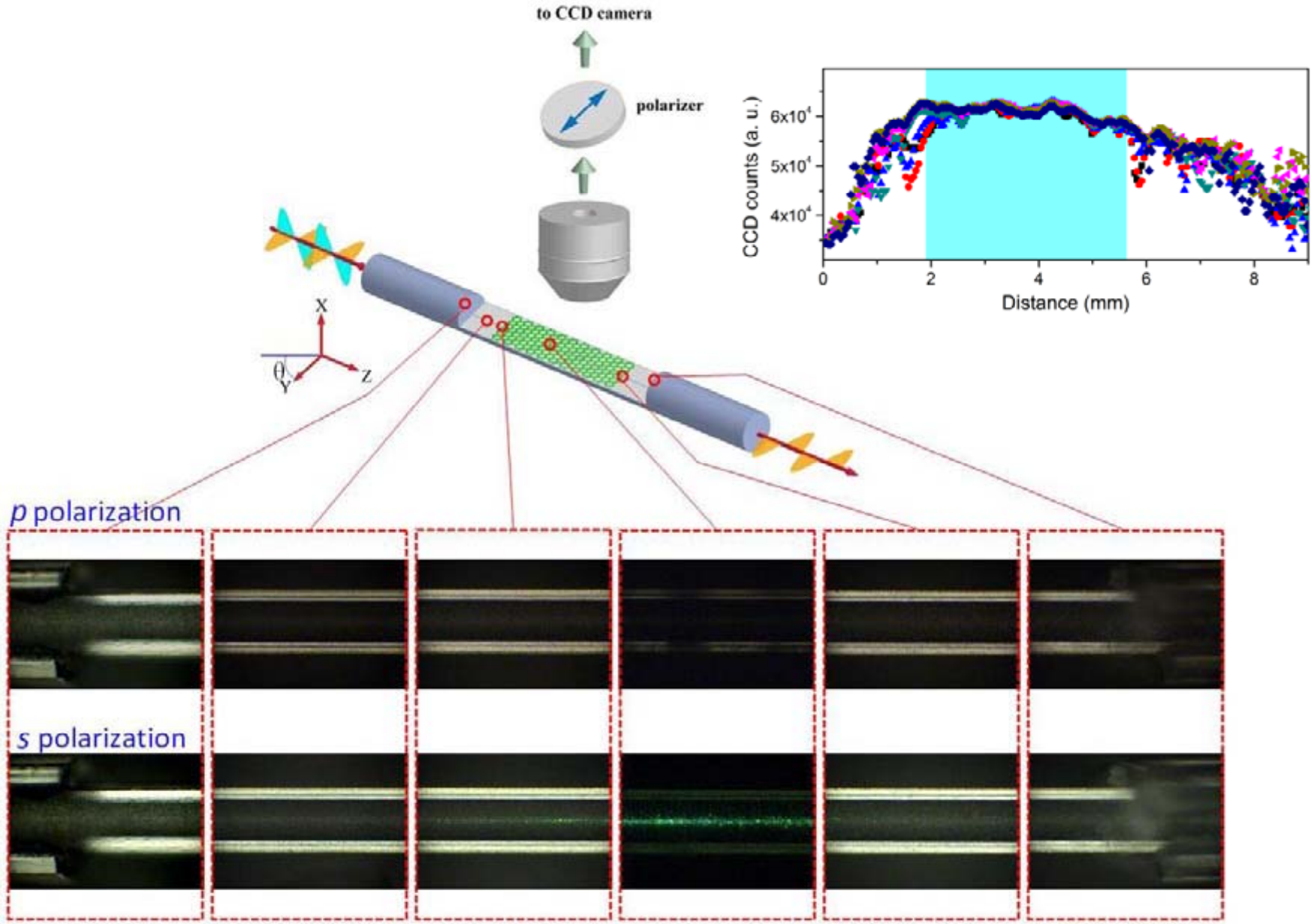

b
c
500 μm

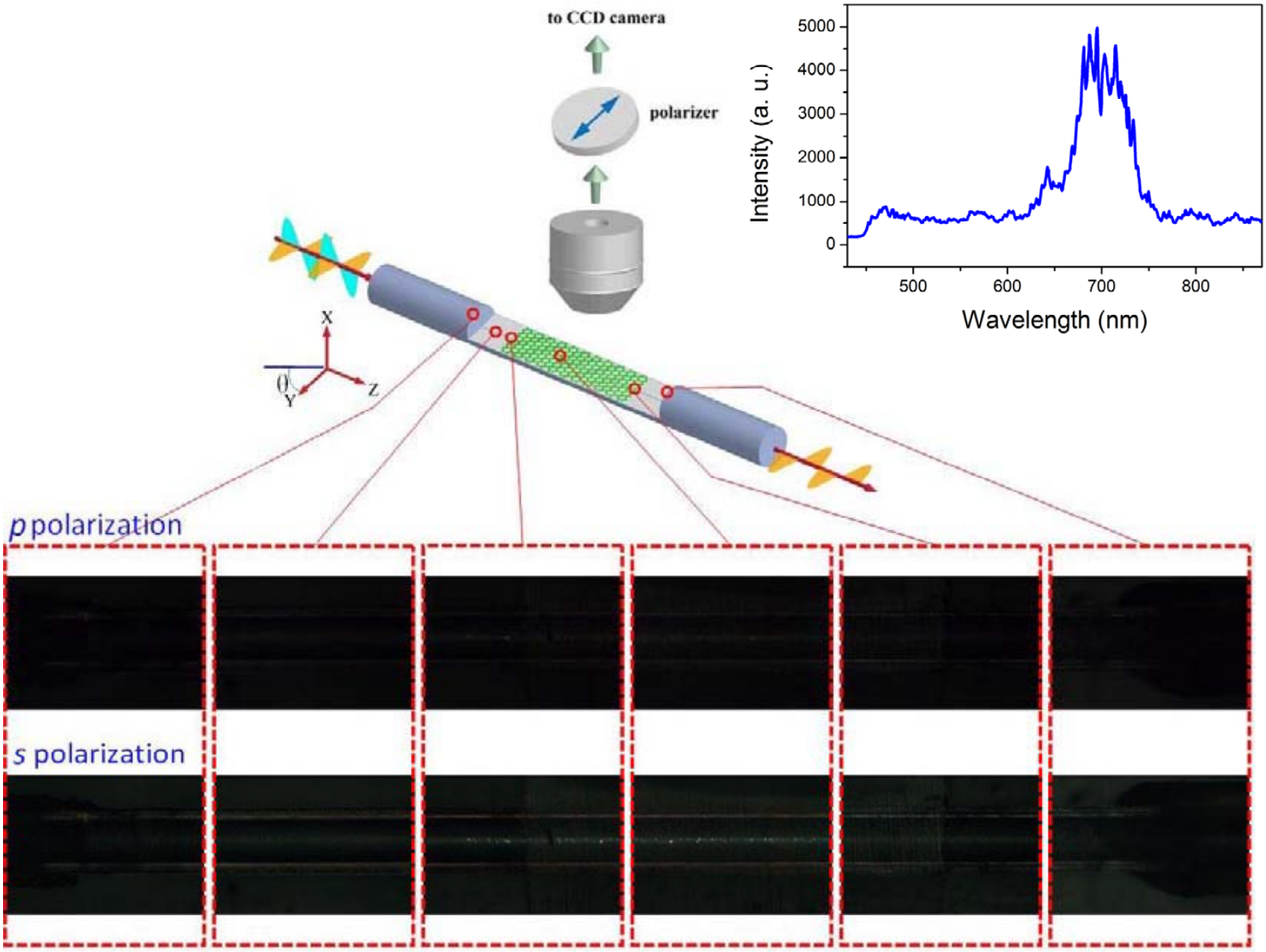

d
Objective lens
Graphene
Optical fibre
Left joint
Right joint
Glass slides

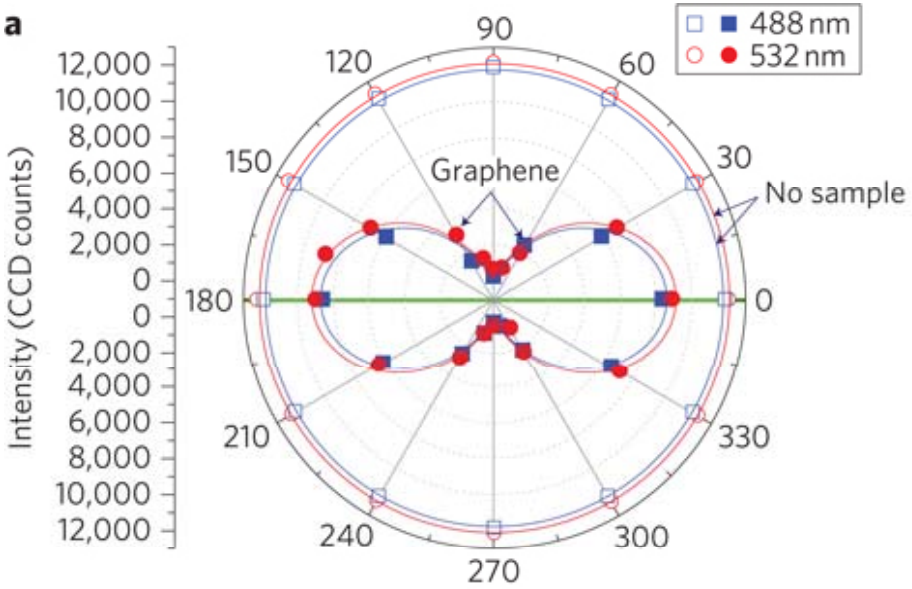

e
s polarization
50 μm
f
p polarization
50 μm



http://hyperphysics.phy-astr.gsu.edu

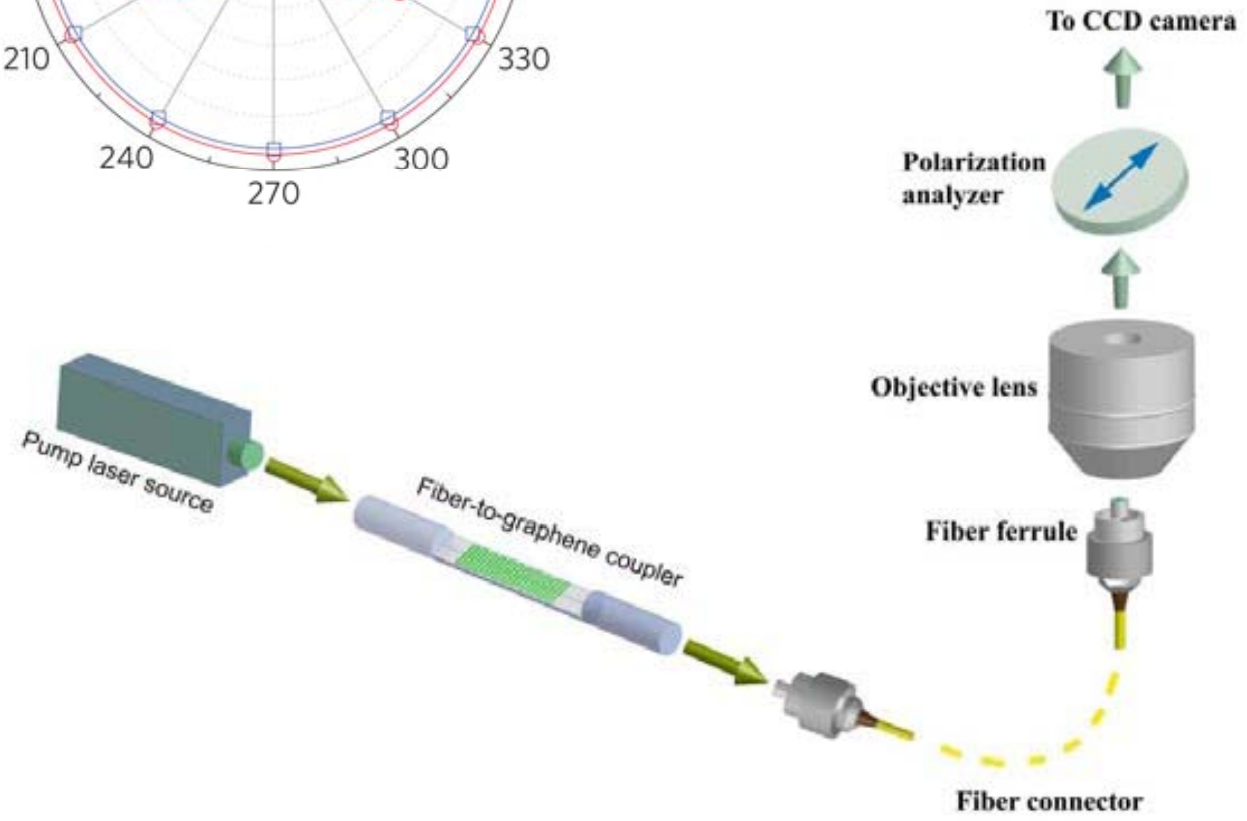

to CCD camera
polarizer
X
Y
Z
θ
CCD counts (a. u.)
6x10⁴
5x10⁴
4x10⁴
0
2
4
6
8
Distance (mm)
p polarization
s polarization

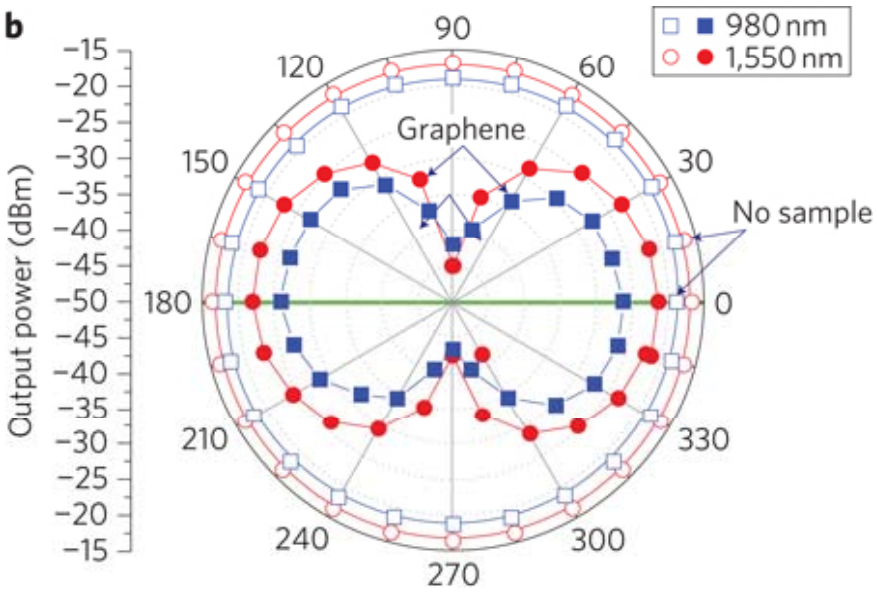

to CCD camera
polarizer
X
Y
Z
θ
Intensity (a. u.)
5000
4000
3000
2000
1000
0
500
600
700
800
Wavelength (nm)
p polarization
s polarization

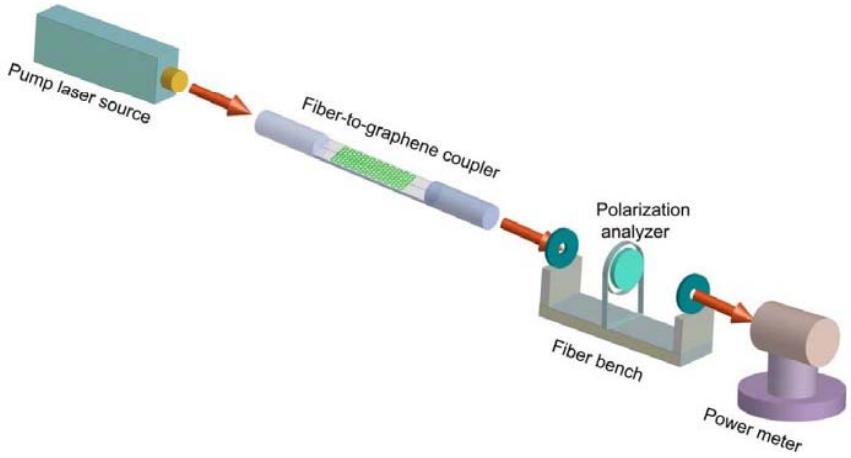

a
488 nm
532 nm
Graphene
No sample
Intensity (CCD counts)
12,000
10,000
8,000
6,000
4,000
2,000
0
0
2,000
4,000
6,000
8,000
10,000
12,000
90
120
60
150
30
180
0
210
330
240
300
270

13.9 dB

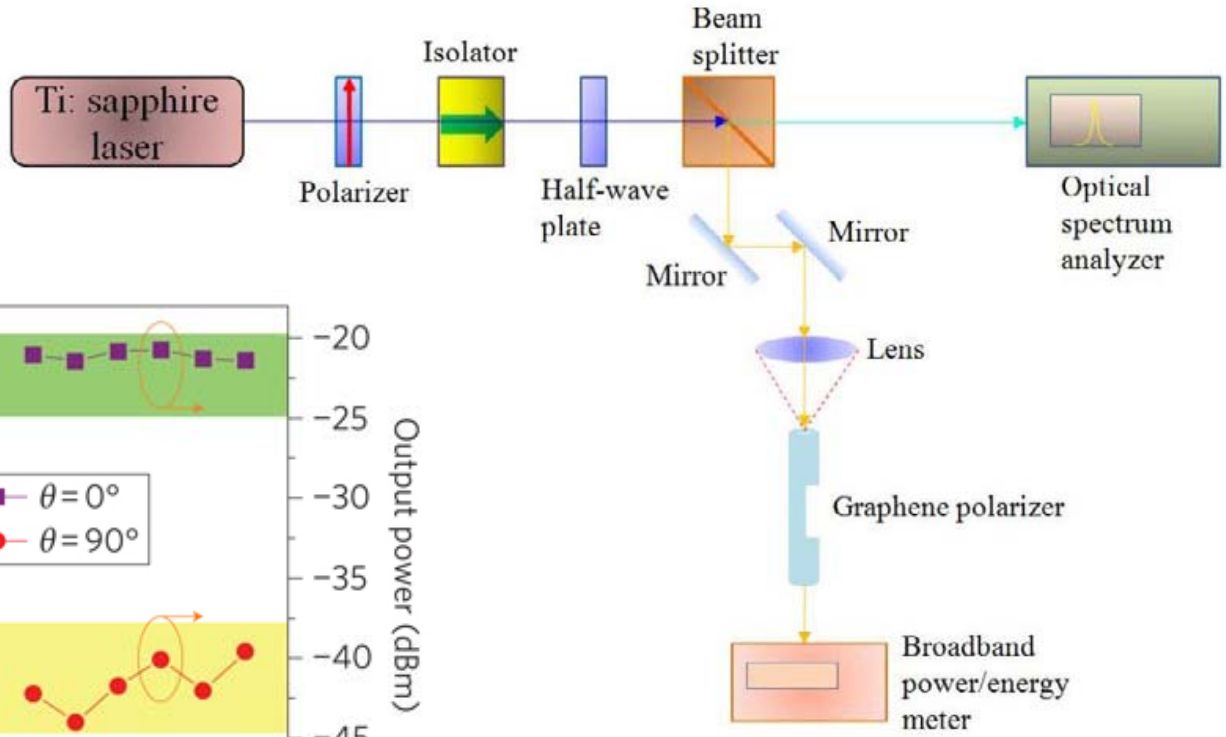
14.2 dB

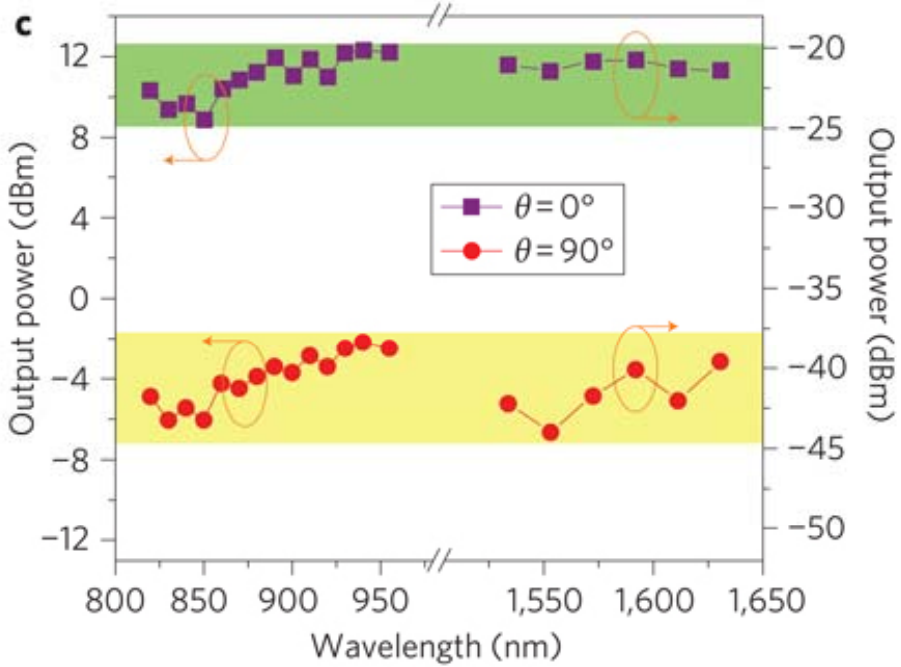

To CCD camera
Polarization analyzer
Objective lens
Fiber ferrule
Pump laser source
Fiber-to-graphene coupler
Fiber connector





980 nm – 18.3 dB
1300 nm - 15.7dB
1480 nm – 18.4 dB
1550 nm – 23.6 dB





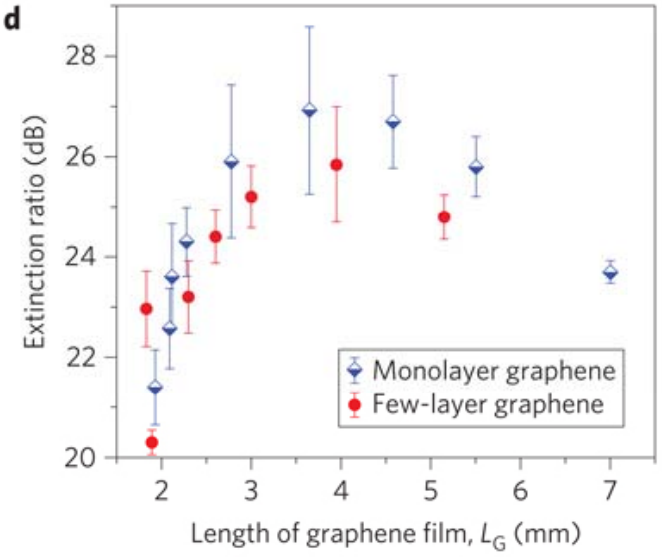
820-955 nm

15+0.6 dB

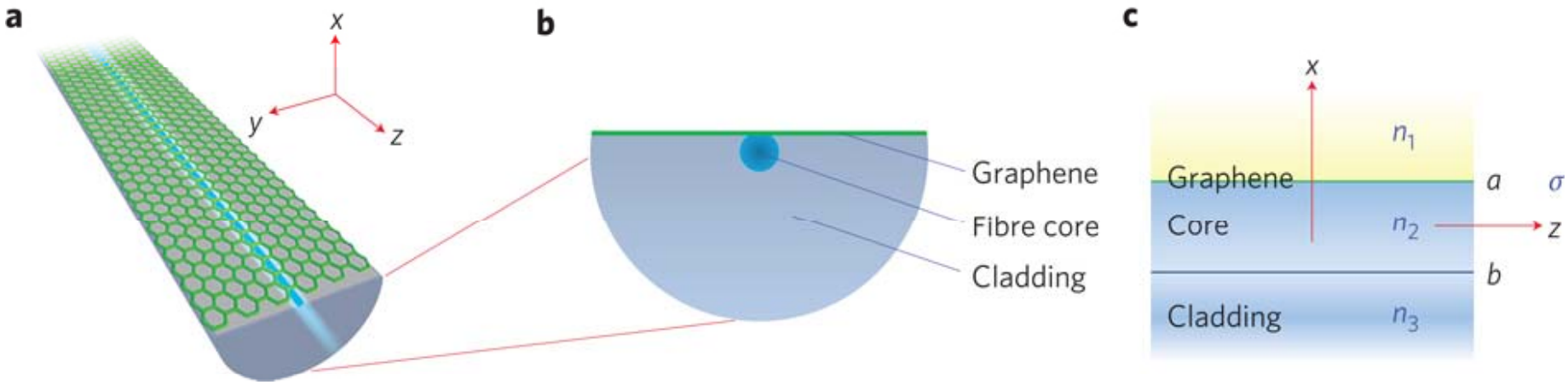
1530-1630

Tele Communication **C** band

18+2.5 dB

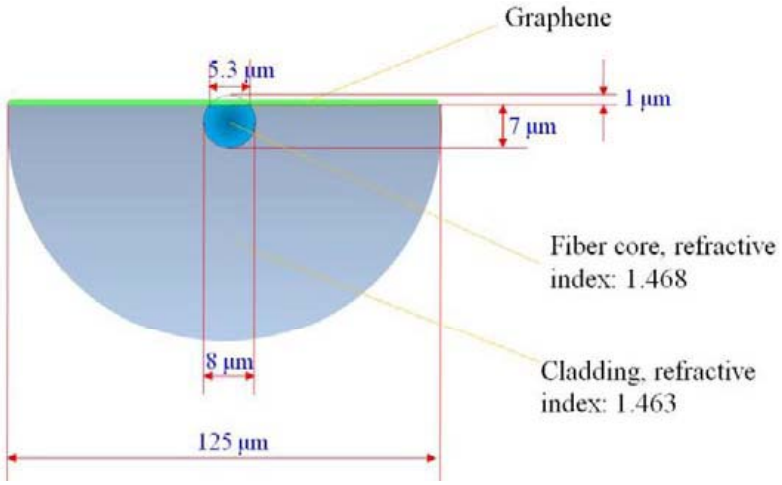


Broad band polarizer



n_1=1.0,
n_2=1.468,
n_3=1.463

Effective index method

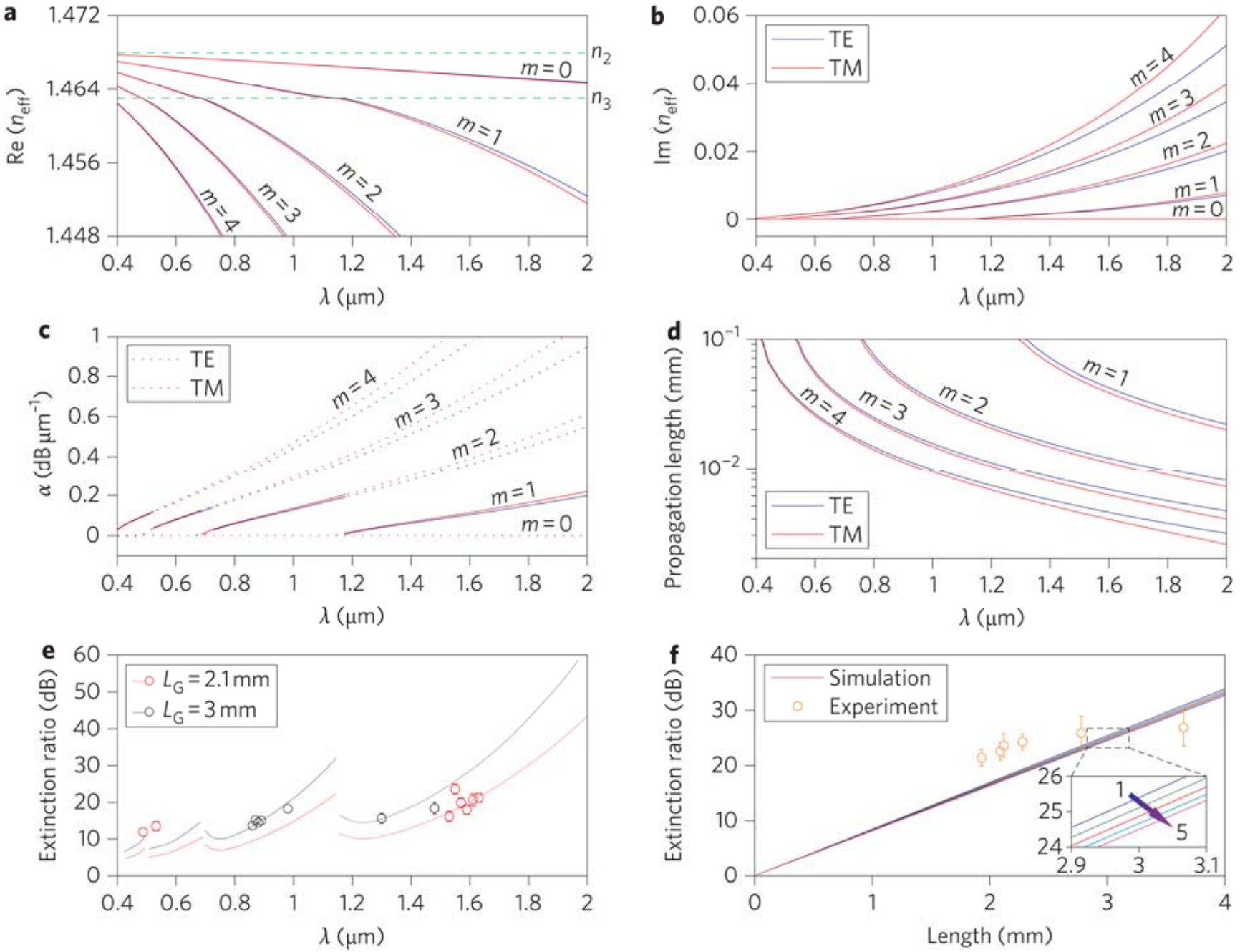


$$1+\frac{2\pi j\sigma(\omega)\sqrt{q^2-\omega^2/c^2}}{\omega}=0$$

$$1-\frac{2\pi j\omega\sigma(\omega)}{c^2\sqrt{q^2-\omega^2/c^2}}=0$$

$$\sigma_{\text{intra}}(\omega)=\frac{je^2\mu}{\pi\hbar^2(\omega+j\tau^{-1})}$$

$$\sigma_{\text{inter}}(\omega)=\frac{je^2}{4\pi\hbar}\ln\left(\frac{2|\mu|-(\omega+j\tau^{-1})\hbar}{2|\mu|+(\omega+j\tau^{-1})\hbar}\right)$$


a
Re (n_{eff})
1.472
1.464
1.456
1.448
n_2
n_3
m = 0
m = 1
m = 2
m = 3
m = 4
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
λ (μm)
b
Im (n_{eff})
0.06
0.04
0.02
0
TE
TM
m = 4
m = 3
m = 2
m = 1
m = 0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
λ (μm)
c
α (dB μm^{-1})
1
0.8
0.6
0.4
0.2
0
TE
TM
m = 4
m = 3
m = 2
m = 1
m = 0
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
λ (μm)
d
Propagation length (mm)
10^{-1}
10^{-2}
m = 1
m = 2
m = 3
m = 4
TE
TM
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
λ (μm)
e
Extinction ratio (dB)
60
50
40
30
20
10
0
L_G = 2.1 mm
L_G = 3 mm
0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
λ (μm)
f
Extinction ratio (dB)
40
30
20
10
0
Simulation
Experiment
26
25
24
1
5
2.9 3 3.1
0 1 2 3 4
Length (mm)

conclusions

- in-plane graphene polarizer was incorporated onto OFC

- The polar plots demonstrates the quality of polarization throughout a broad range of EM spectrum

- The graphene unique electronic structure plays crucial role in allowing the TE mode

- Coupling and confinement by graphene induces higher order leaky modes to filter out TM modes

Thank you all

Robin John
Ph08d023
20/08/2011