NANO-SWIR

NANOscale Materials for Next-Generation SWIR-MWIR Pixel Sensors

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Nuova proposta 2026

3 INFN Units: PISA, ROMA2, PAVIA

SWIR=Small Wave InfraRed (λ=1-3 μm)
MWIR=Medium Wave InfraRed (λ=3-8 μm)

NANO-SWIR new proposal

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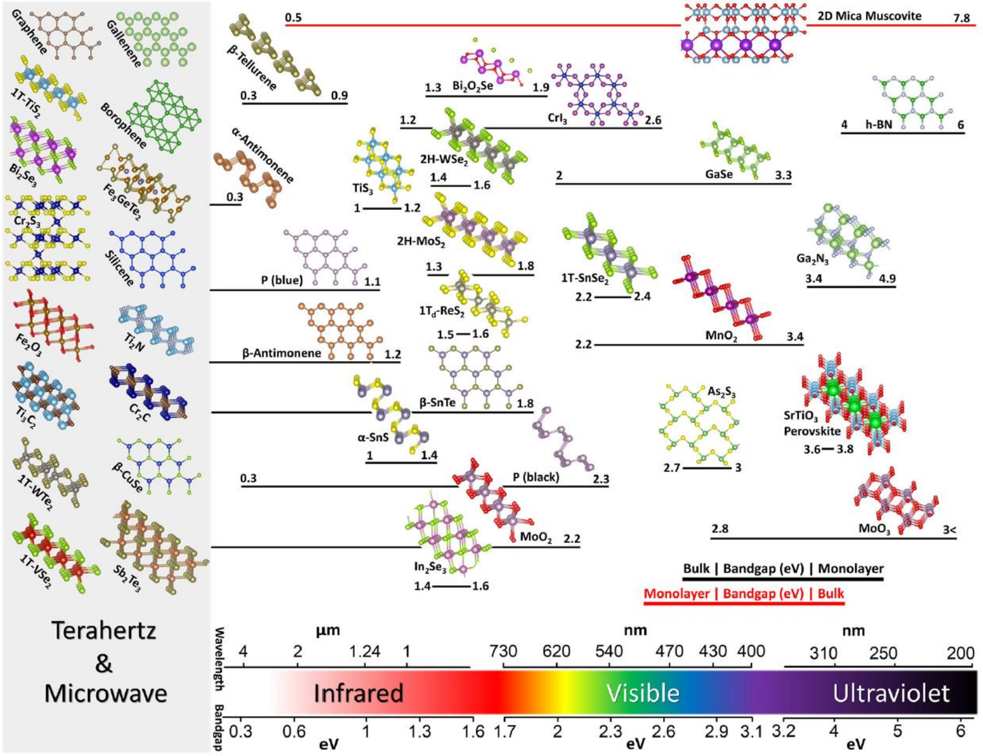
Use of van der Waals materials absorbing in different selected wavelength ranges between 1 μm and 8 μm with the goal to realize a multipixel detector working as spectrometer.

The selected materials will be grown in form of single crystal nanobelts, nanowires or nanoplatelets with high charge carrier mobility.



Synthesis of bismuth sulfide nanobelts for high performance broadband photodetectors†

Jinzhuo Xu,[a] Henan Li,*[b] Shaofan Fang,[a] Ke Jiang,[a] Huizhen Yao,[a] Feier Fang,[a] Fuming Chen,[c] Ye Wang[d] and Yumeng Shi *[ae]

Broadband photodetectors are critical to modern industrial systems and scientific applications and have attracted broad attention in recent years. In this paper, high quality single-crystal Bi_2S_3 nanobelts were prepared by using the chemical vapor deposition (CVD) method. The Bi_2S_3 nanobelts were further used as photosensitive materials for broadband photo-detection. The as-grown Bi_2S_3 nanobelts exhibit ultrahigh absorption coefficiency in the ultraviolet (UV) to near infrared (NIR) range. The photodetectors based on a single Bi_2S_3 nanobelt showed excellent broadband photoresponse performance in the UV to NIR range (from 300 to 1000 nm), including high photoresponsivity up to 201 A W^{-1}, an ultrafast response speed of ~50 μs, a high external quantum efficiency of 31 140% and a high detectivity of 2.7×10^{10} Jones. The superior performance can be attributed to the ultrahigh absorption coefficiency of Bi_2S_3 nanobelts, as well as the Schottky contact between the Bi_2S_3 nanobelt and the Au electrode. The present work suggests that the single-crystal Bi_2S_3 nanobelts possess great potential for the fabrication of high performance broadband photodetectors.

SWIR-MWIR: Small (λ=1-3 μm) Wave Infrared -Medium (λ=3-8 μm) Wave Infrared

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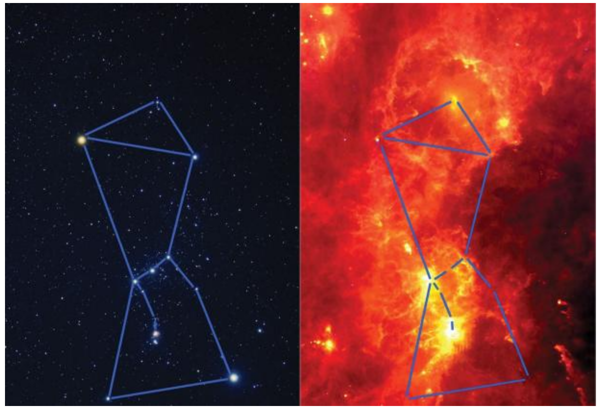
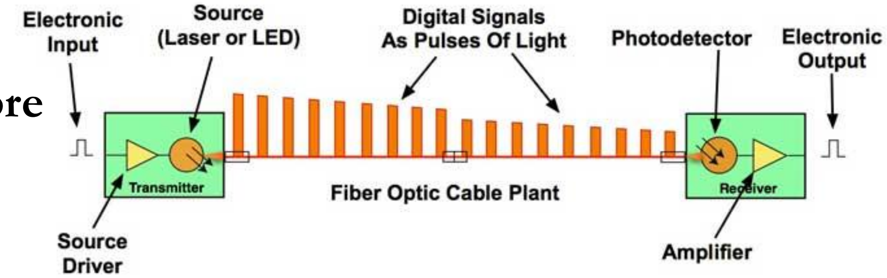
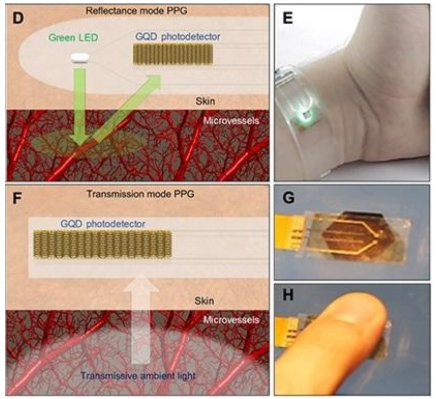
DETECTOR APPLICATIONS



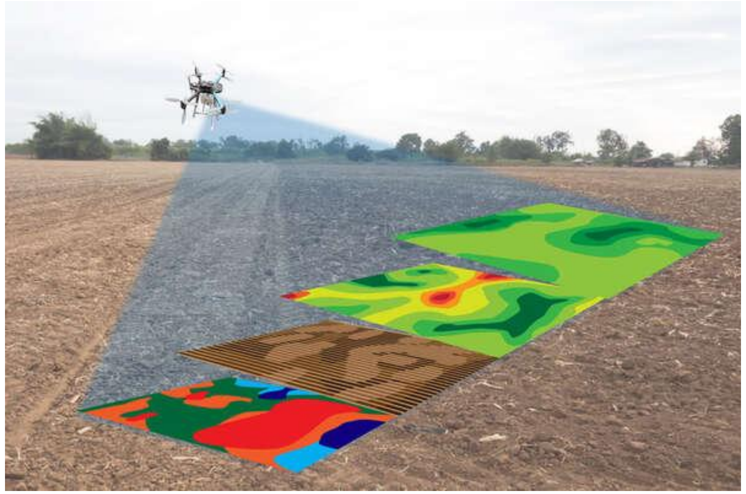
Infrared Astronomy

Detectors for optical fibre transmitted signals





Biomedic flexible sensors

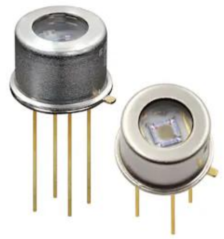


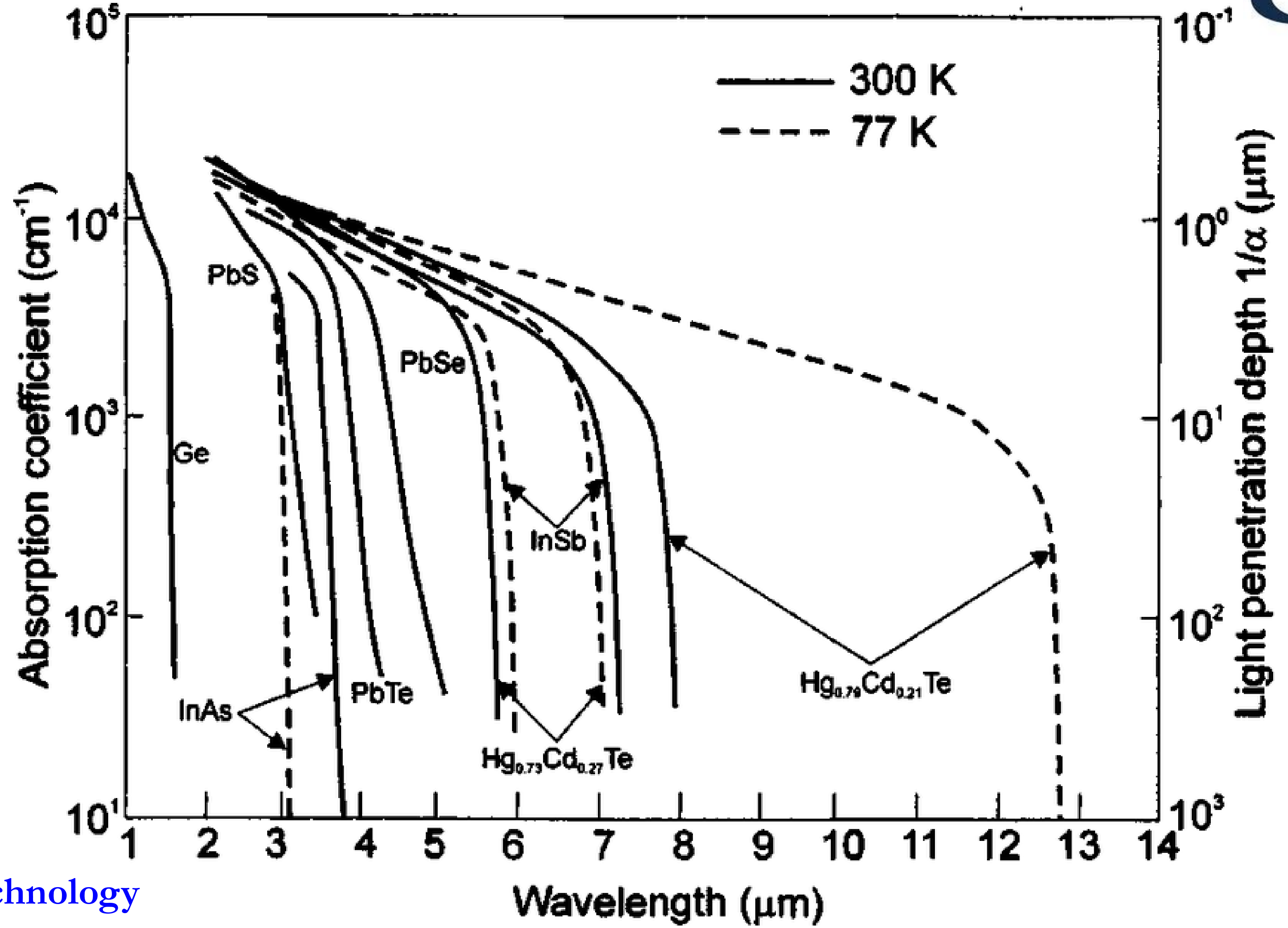
Precision Farming

LiDAR (Light Detector And Ranging)

Most used materials:

- Ge λ_G=1550 nm
- $In_{0.53}Ga_{0.47}As$ λ_G=1.7 μm
- InSb λ_G=6-7 μm
- $Hg_xCd_{1-x}Te$ λ_G=6-8 μm





- High cost
- Low compatibility with CMOS technology
- Low temperature operation
- Harmful enviromental compatibility

Van der Waals materials for high responsivity IR photodetectors

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Comparative table of key performance parameters (Responsivity, Detectivity, Spectral Range, Response Time) for 2D heterostructure IR photodetectors.

Material	Device configuration	Responsivity (AW^{-1})	Detectivity (Jones)	Spectral Range	Response Time (s)	Ref.
2D/0D	Graphene/PbS QD	10^7	7×10^{13}	VIS-SWIR	10^{-2}	[108]
	Graphene/PbS QD	10^7	–	NIR	0.3	[109]
	MoS_2/PbS QD	10^5-10^6	$\sim 10^{14}$	VIS-SWIR	0.35	[110]
	MoS_2/PbS QD	10^7	5.5×10^{15}	NIR	0.17	[111]
	PbS/MoS_2	5×10^4	3×10^{13}	NIR	7.8×10^{-3}	[112]
	PbS/MoS_2	5.43×10^{-2}	2.68×10^{12}	SWIR	–	[113]
	MoS_2/HgTe QD	$\sim 10^5$	$\sim 10^{12}$	SWIR	Sub-millisecond	[114]
	Ti_2O_3/Gr	3.0×10^2	7×10^8	SIR	1.2×10^{-3}	[39]
	MoS_2/PbS	1.376×10^2	7.7×10^{10}	NIR	–	[115]
	MoS_2/HgTe	1.05×10^2	10^{12}	NIR	–	[114]
	Si/Gr	4.49×10^1	10^5	VIS-NIR	–	[60]
2D/1D	Te/MoS_2	$> 10^3$	10^{12}	–	15×10^{-3}	[116]
	$PdSe_2$/SiNWA	–	–	VIS-SIR	–	[69]
	$PdSe_2$/Ge NCs	5.3×10^{-1}	1.45×10^{11}	NIR	2.2×10^{-5}	[117]
	Bi_2Te_3/Gr	9×10^{-5}	–	VIS-NIR	–	[118]
	CdS_xSe_{1-x}/Te	2.84×10^2	1.07×10^{17}	VIS-NIR	11×10^{-6}	[119]
2D/2D	Graphene/MoS_2	10^7	–	MWIR-LWIR	–	[120]
	Graphene/MoS_2	3×10^4	1.7×10^{-9}	NIR	–	[121]
	Graphene/BP	3.3×10^3	–	SWIR	4×10^{-3}	[122]
	MoS_2/BP	1.534×10^{-1}	2.13×10^9	SWIR	15×10^{-6}	[77]
	MoS_2/BP	9.0×10^{-1}	1.1×10^{10}	MWIR	4×10^{-6}	[81]
	BP/WSe_2	5.0×10^{-1}	$\sim 10^{10}$	SWIR	0.8×10^{-3}	[93]
	BP/Graphene	5.0×10^{-2}	6.69×10^8	Vis-MWIR	–	[123]
	BP/MoS_2	3.7×10^{-3}	–	NIR-MWIR	–	[81]
	b-AsP/MoS_2	–	10^9	–	–	[80]
	WS_2/HfS_2	$>10^3$	$>10^{10}$	Vis-LWIR	1.7	[124]
	Graphene/Bi_2Se_3	1.97	1.6×10^9	NIR-MWIR	4×10^{-3}	[125]
	$PdSe_2$/MoS_2	2.883×10^1	6.09×10^{10}	UV-LWIR	–	[36]
	FG/Graphene	5.0×10^1	6×10^9	UV-MWIR	100	[126]
	Te/MoS_2	8.7×10^{-1}	7.8×10^8	NIR-MWIR	–	[127]
	Te/Graphene	9.6×10^{-3}	1.04×10^9	NIR-MWIR	2.8×10^{-3}	[128]
	$MoTe_2$/BP	–	3.4×10^9	UV-MWIR	–	[129]
	Graphene/InSb	–	–	Vis-LWIR	–	[130]
	$MoTe_2$/Ge	1.246×10^4	3.3×10^{12}	NIR	5×10^{-3}	[131]
2D/3D	GeSn/Graphene	2.2×10^2	2.96×10^{11}	NIR-SWIR	10	[132]
	Bi_2Se_3/Si	2×10^4	1.2×10^{10}	Vis-NIR	23	
	b-As/Si	7.522×10^1	3×10^9	UV-MWIR	–	
	$PtTe_2$/Si	$>1.2 \times 10^6$	–	Vis-LWIR	–	
	MoS_2/a-Si:H	5×10^{-2}	2×10^{10}	Vis-NIR	–	
	Graphene/Ta_2O_5	7.2	8×10^6	UV-LWIR	1	
	Graphene/Si	1.3×10^{-1}	–	NIR-MWIR	–	
	HgCdTe/BP	1.68×10^{-1}	1.81×10^{10}	NIR-MWIR	–	
	WS_2/Si	–	–	UV-NIR	–	
	BP/Bi_2O_2Se	–	3×10^9	–	–	
	$PtTe_2$/Si	5×10^{-3}	6.92×10^9	UV-LWIR	2.4×10^{-3}	
	Te/Si	2.49×10^2	1.15×10^{11}	UV-NIR	3.7×10^{-3}	

- Very recent
- CMOS compatible and Si integration
- Operating in the range IR-UV
- High Responsivity

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ELSEVIER

Van der Waals heterostructures for advanced infrared photodetection: Innovations in stability and spectral range

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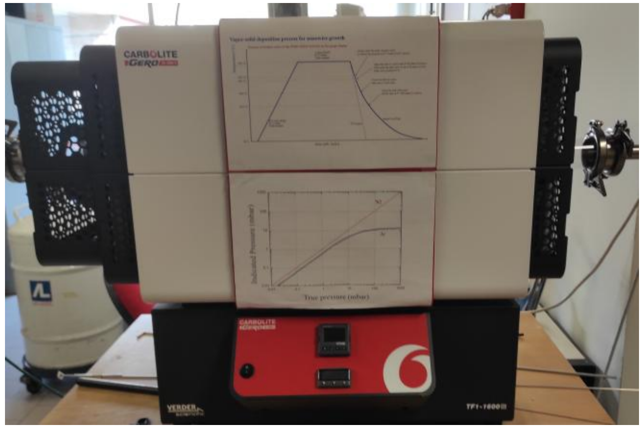
[b] Institute of Infrastructure Technology Research and Management, Ahmedabad, 380026, India

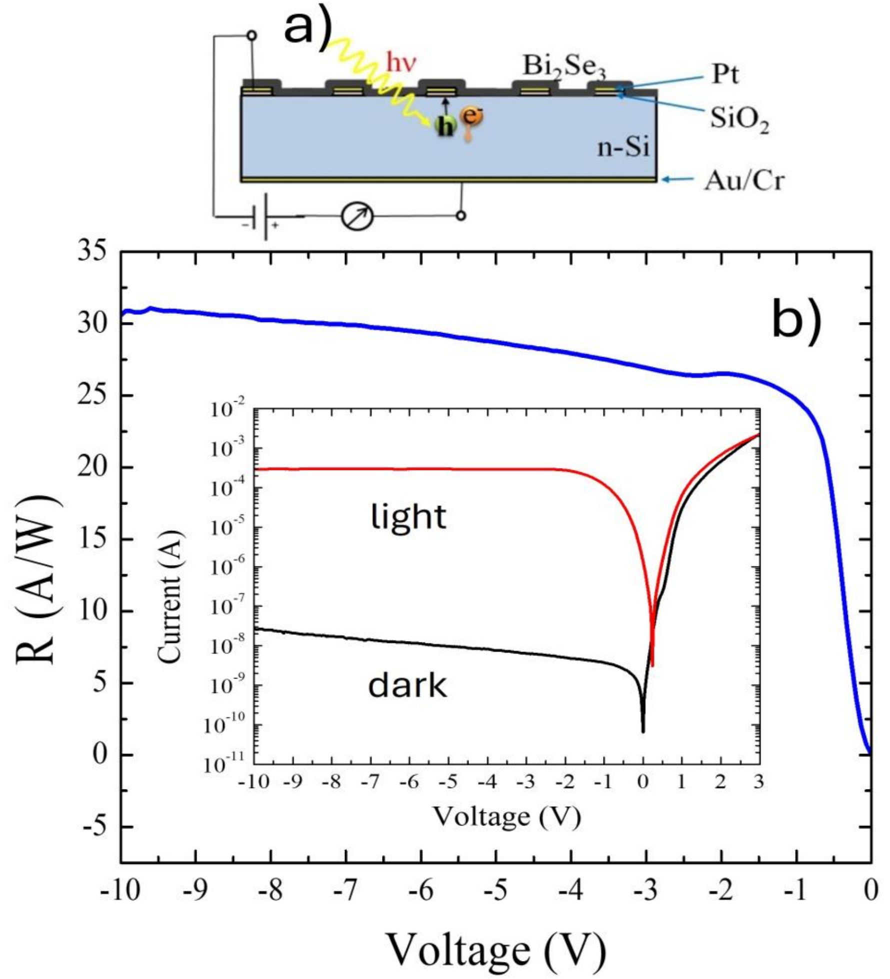
Some 2D materials are grown at ROMA2 INFN Unit in form of thin films by vapor solid deposition…

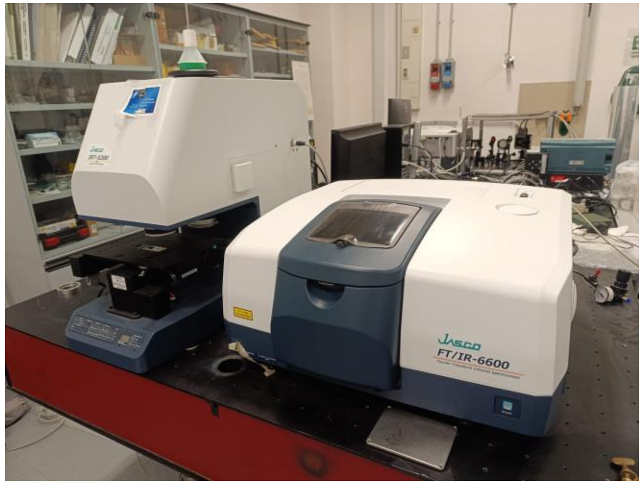
Bi_2Se_3/Si junction @ ROMA2 showing Responsivity up to 40 A/W



Single zone furnace

Three zone furnace

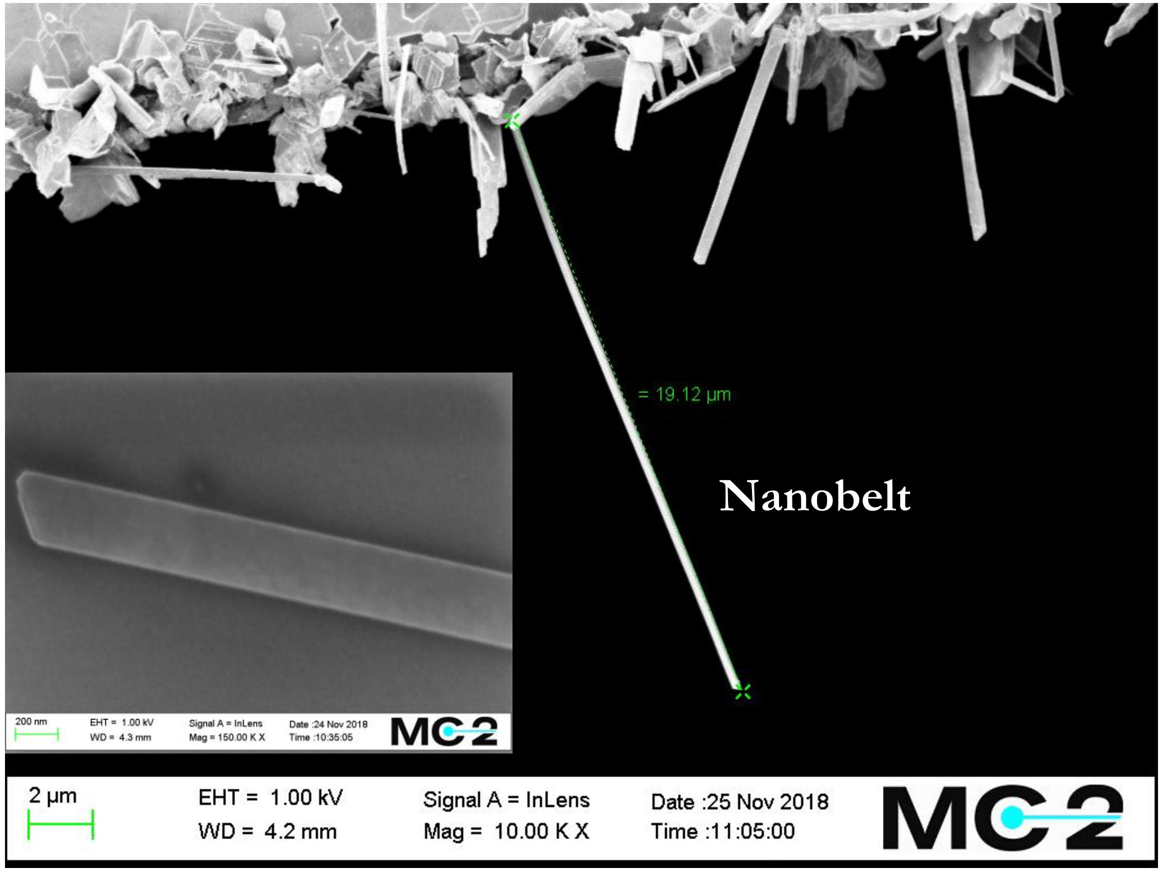




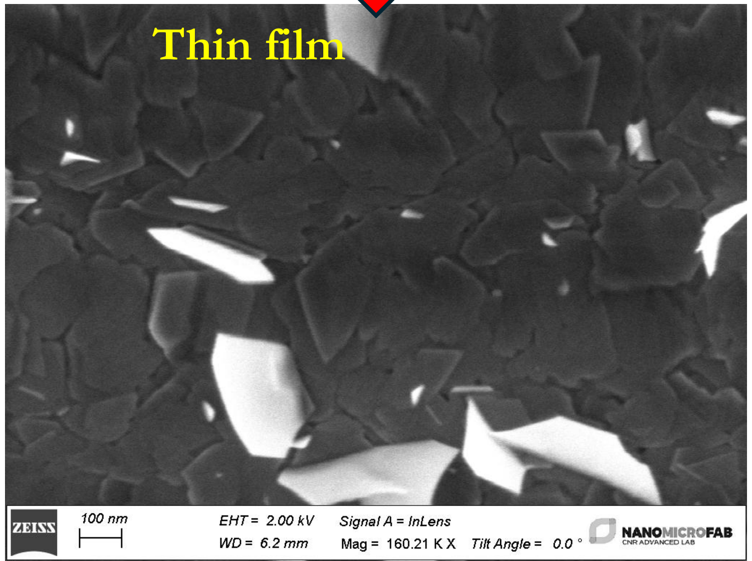
Spectrometer VIS-IR

…And electro-optically characterized by absorbance and current-voltage measurements

Bi2Se3 nanostructures grown @ROMA2 by VSD



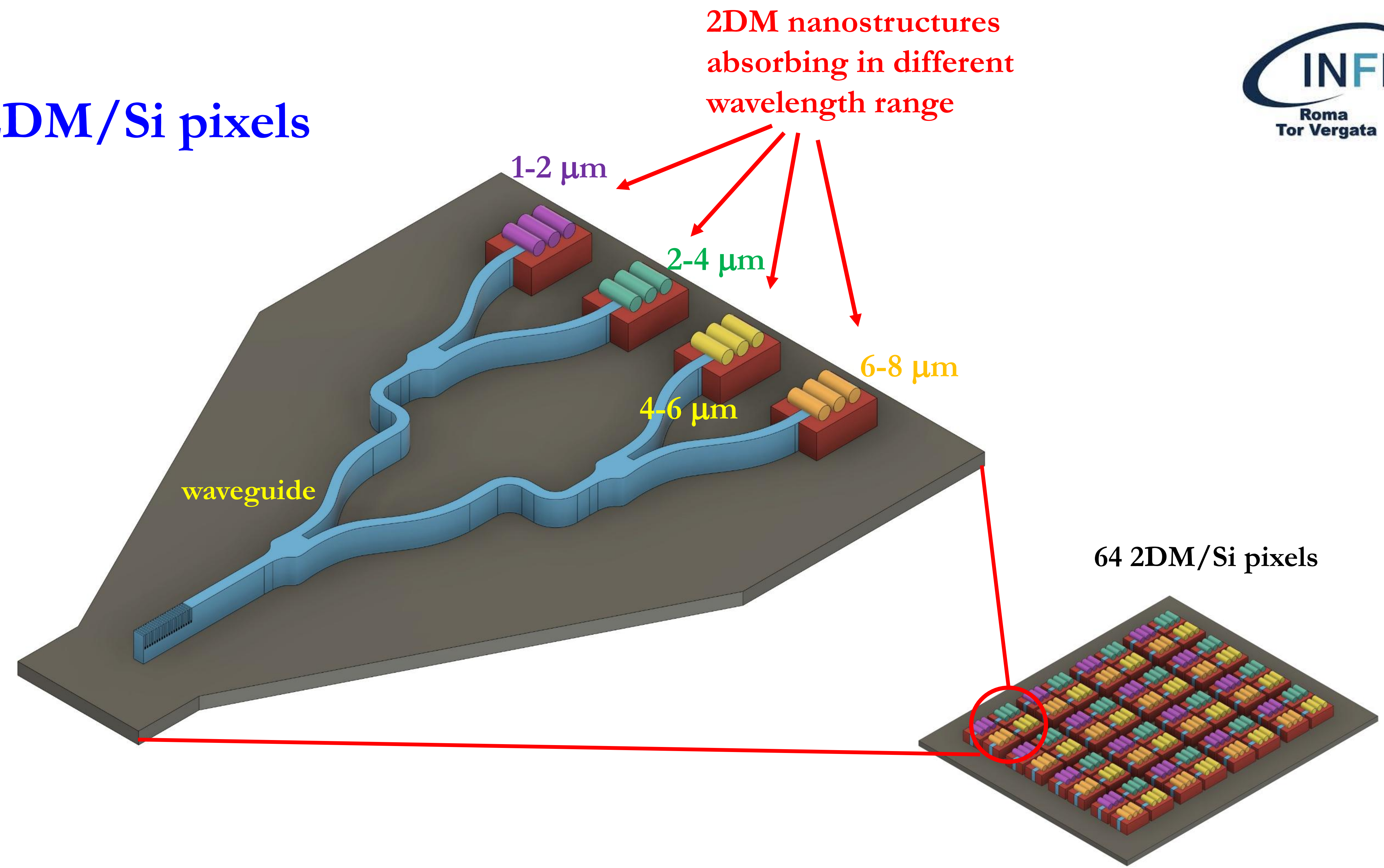
Nanobelts present single crystal lattice structure which favours the high charge mobility=HIGH RESPONSIVITY



Thin films are granular with low charge mobility=

=LIMITED RESPONSIVITY

4 2DM/Si pixels



INFN PISA Principal Investigator: Franco Spinella

Multipixel production and electro-optical measurements

INFN ROMA2 Local Coordinator: Matteo Salvato

Growth of nanostructures and electro-optical measurements

INFN PAVIA Local Coordinator: Vittorio Bellani

Nanomanipulation of the nanostructures on multipixel

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Roma 2 Research Unit	2026	2027	2028
Matteo Salvato	0.5	0.6	0.3
Fabio De Matteis	0.2	0.6	0.5
Paola Castrucci	0.4	0.4	0.2
Luca Camilli	0.2	0.2	0.2
Filippo Pierucci	0.3	0.2	0.2
Totale	1.6	2.0	1.4

Project costs @ INFN ROMA2

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Most of the equipment is available @Roma2 partially financed by other INFN projects as QUANTEP

Mainly costs are for consumables:

- Tubes for material evaporation
- Evaporation materials
- Substrates
- Gases
- Water purification
- Source meter
- Optical accessories

Costs in k€	2026	2027	2028	Total
Travels	2	2	2	6
Consumables	25	13	8	46
Equipements	0	8	0	8
Total	27	23	10	60

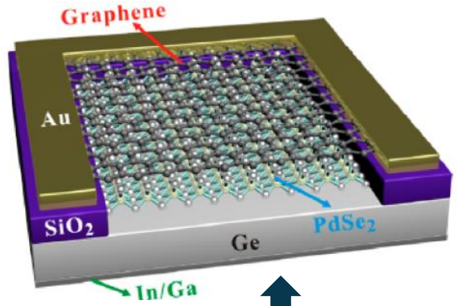
Project costs @ INFN ROMA2 during the three years of the Project

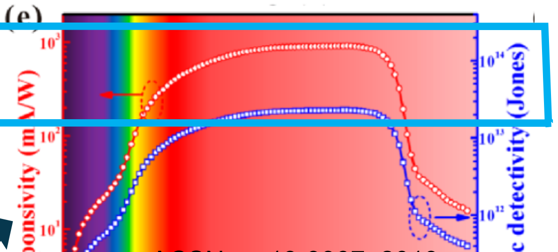
Total costs of the Project in 3 years for 3 Units: 180 k€

Cosa si propone il progetto ?
Fase 1: caratterizzazione dei materiali

- Caratterizzare la risposta spettrale di diversi materiali
- Sceglierne 4 che coprono la banda 1-8 um con la massima responsivita' e separazione spettrale

Material	structure	bandgap eV	Substrate	wavelength um	responsivity A/W
PdSe2/Si	thin film	:V for 50 to 5 layers			0,3
Bi2O2Se/PbSe	Q-dots			2	3000
WS2/PbS	Q-dots			1,8	1400
Bi2Te3/Gr	nanowire	0,35		0.94-1.72	10^6
PdSe2/MoS2	film/flake			10,6	42,1
WS2/Bi2Se3	flake/film			1.064	26,7
Bi2Te3/Gr	nanoplatelets			1,55	0,22
Te/Si	film	0,35			
PdSe2/Ge	thin film			0.2-3.034	1000
PtSe2/Ge				1,55	0,6
MoS2/Si	thin film			0.45-1.050	
PbSe	thin film			4.5-10	125





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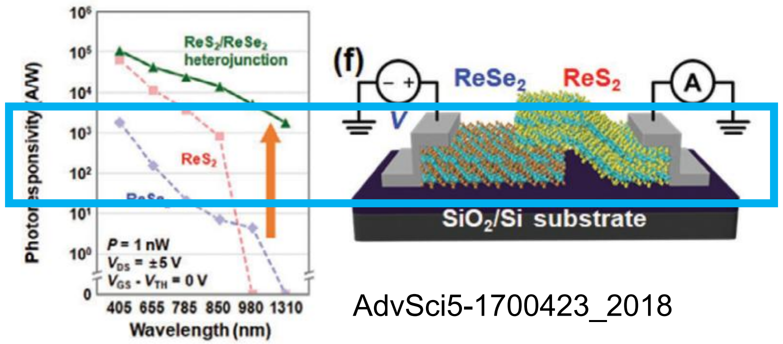

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