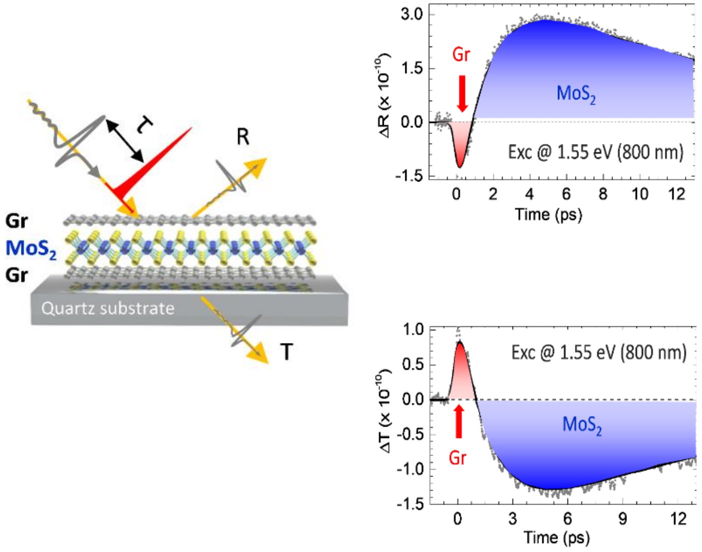
THz conductivity and photo-induced carrier dynamics in a Graphene/MoS_2/Graphene heterostructure



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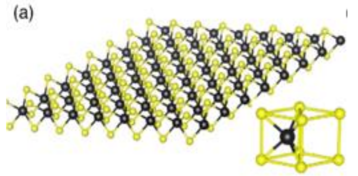
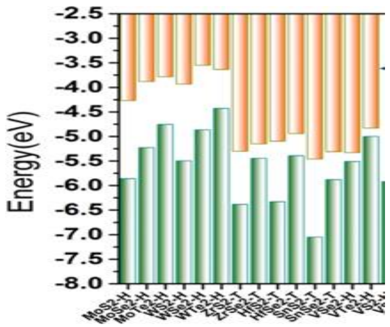
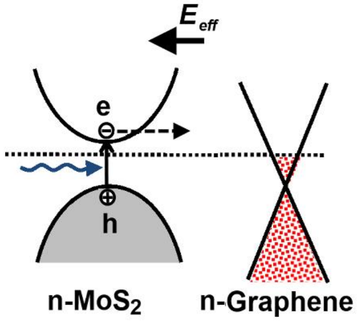
Introduction



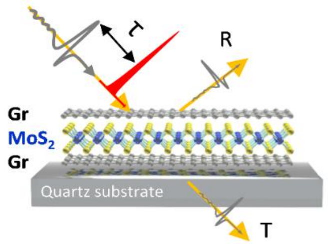
Single layer of transition metal dichalcogenite (TMDC) such as MoS_2, WS_2, $MoSe_2$, are 2D materials which offer many prospects in optoelectronics, optics, etc...



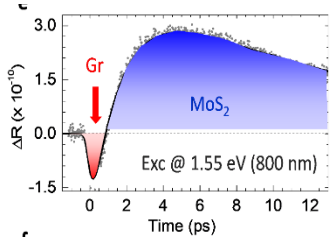
Heterostructures of semiconducting TMDC's can be easily prepared to further extend the range of applications of these materials and give rise to new type of excitons where e^- and hole are localized in different layers of TMDC.



Heterostructure of TMDC with graphene have also been prepared and studied. It has been shown that when excited above the band gap of the TMDC the e^- are rapidly transferred from TMDC to graphene.



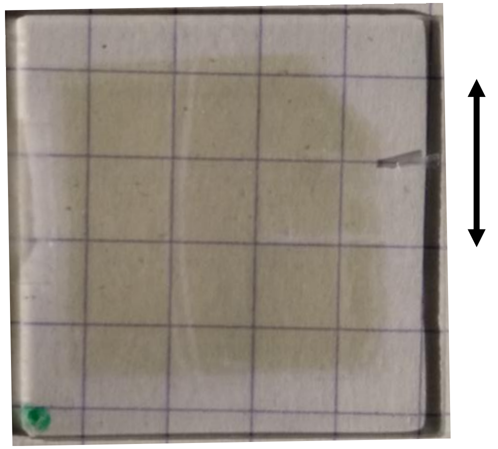
We have prepared a Graphene/MoS_2/Graphene heterostructure. Using optical absorption, Raman spectroscopy and TDS-THz spectroscopy we characterized the properties of this heterostructure.



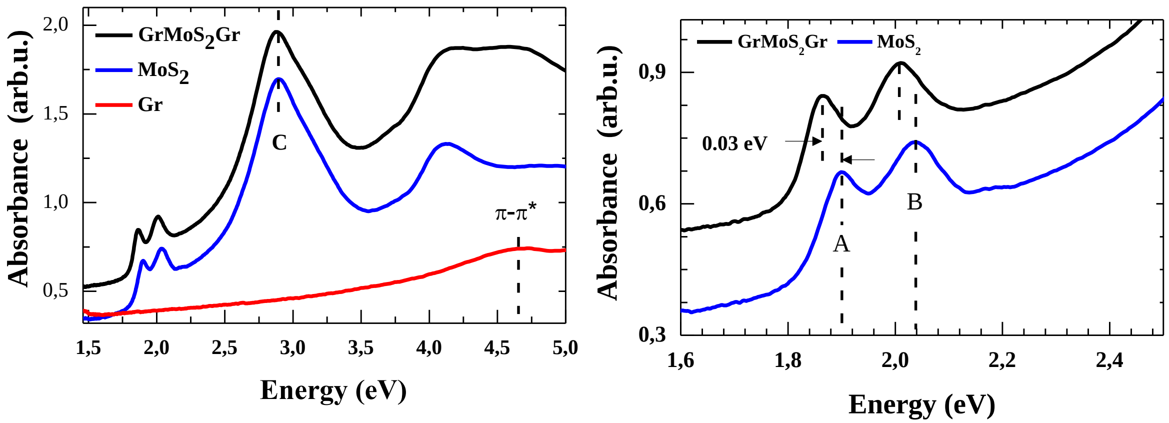
Time resolved optical-pump THz-probe experiment indicates that below the band gap of MoS_2 carriers generated in graphene can be transiently tranfered in MoS_2

Studied sample and their characterisations.

Large CVD grown samples of Graphene (Gr), MoS_2 and Gr/MoS_2/Gr transferred on quartz

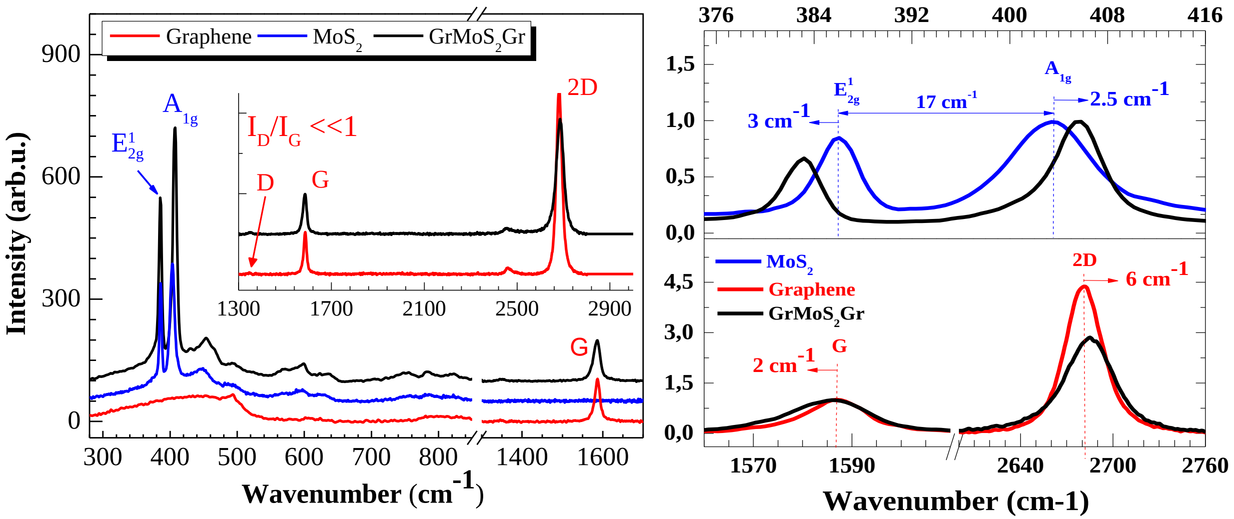


Absorption spectra in visible and U.V. range



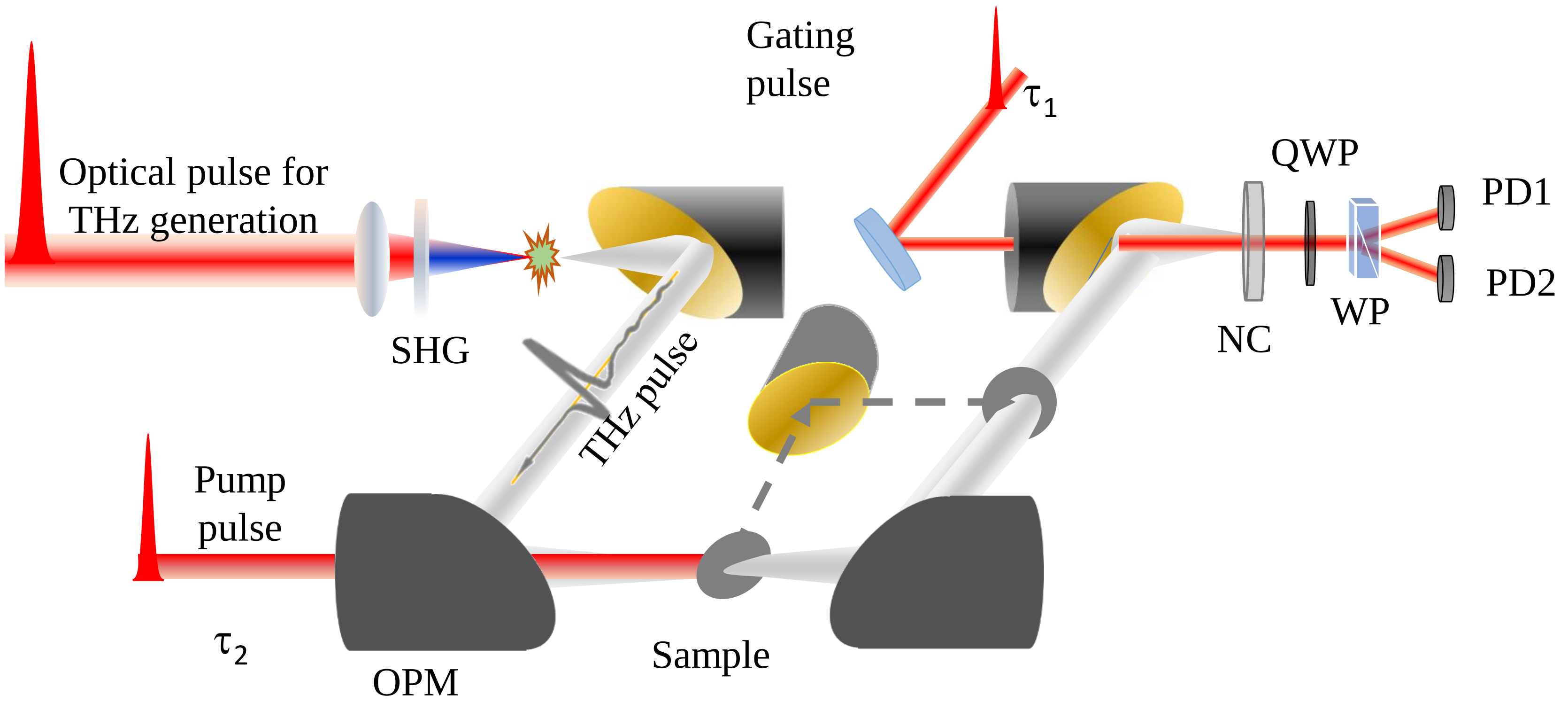
A, B and C exciton at ~1.86 eV, ~2.01 eV and 2.70 eV in MoS_2
Band Gap in MoS_2 ~1.90 eV

Raman spectra

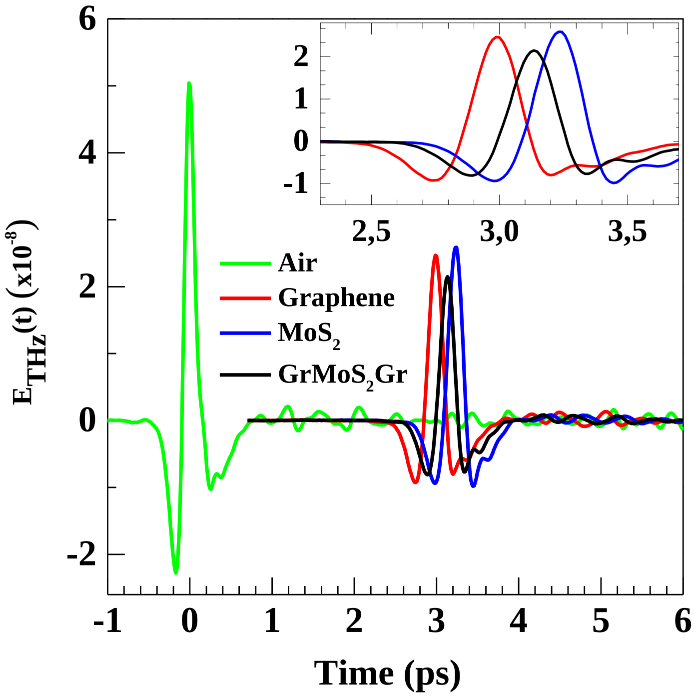


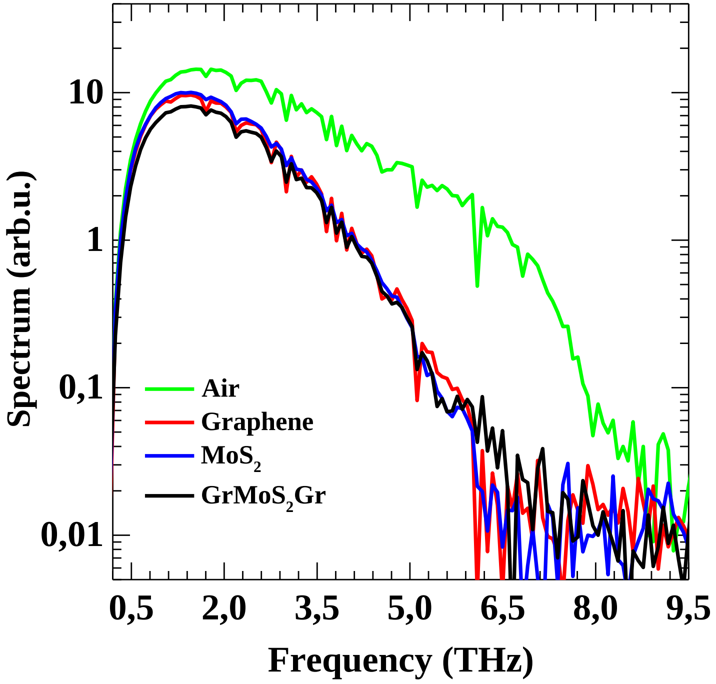
In Graphene I_{2D}/I_G = 2 and I_D mode characterizes the defects

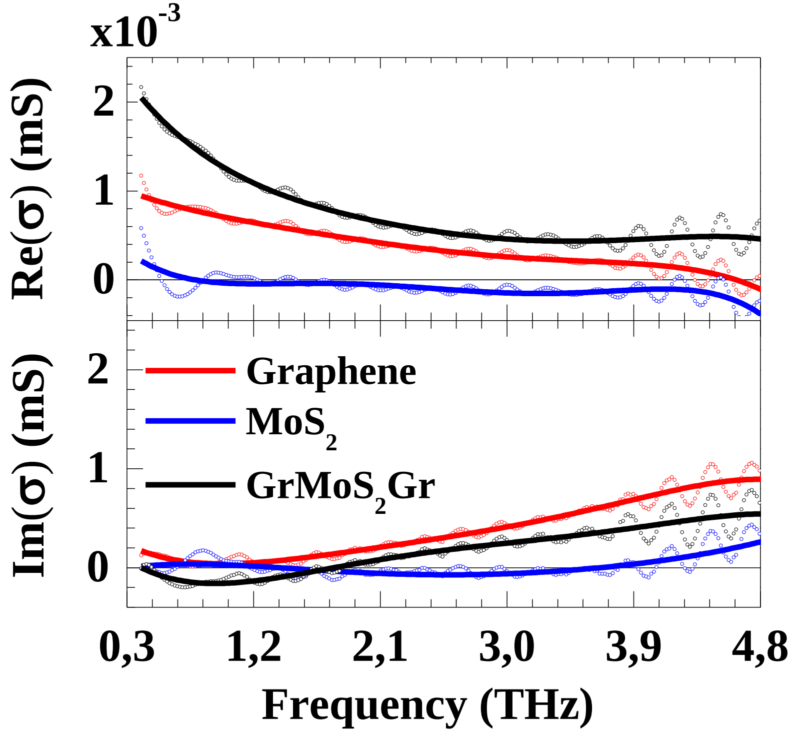
THz-TDS spectroscopy and Optical pump – THz probe set-up



THz -TDS of the studied samples







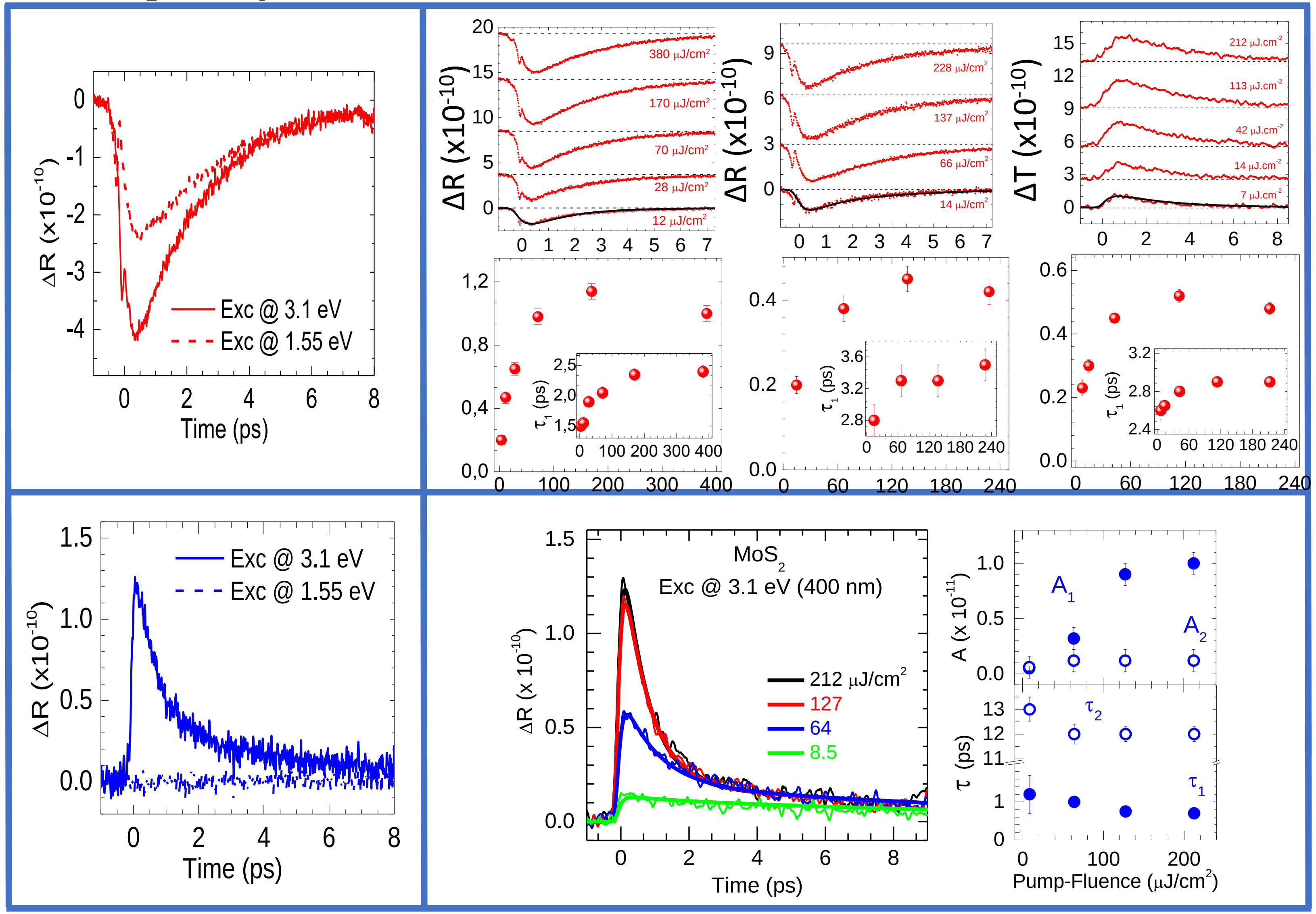
Optical pump – THz probe on Graphene and MoS_2

Pump = 20 µJ. cm^{-2}

Exc. @ 3.1 eV (400 nm) Exc. @ 1.55 eV (800 nm) Exc. @ 1.55 eV (800 nm)

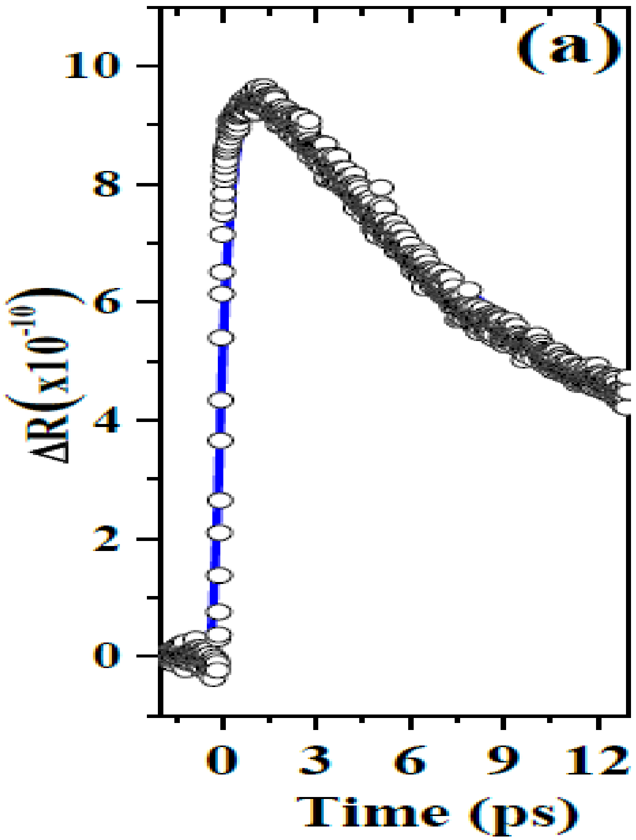
Graphene

MoS_2

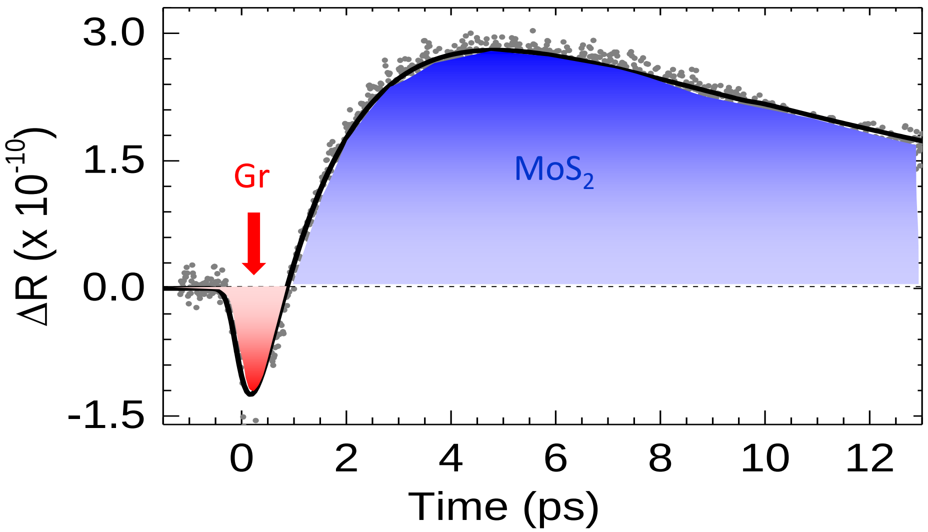


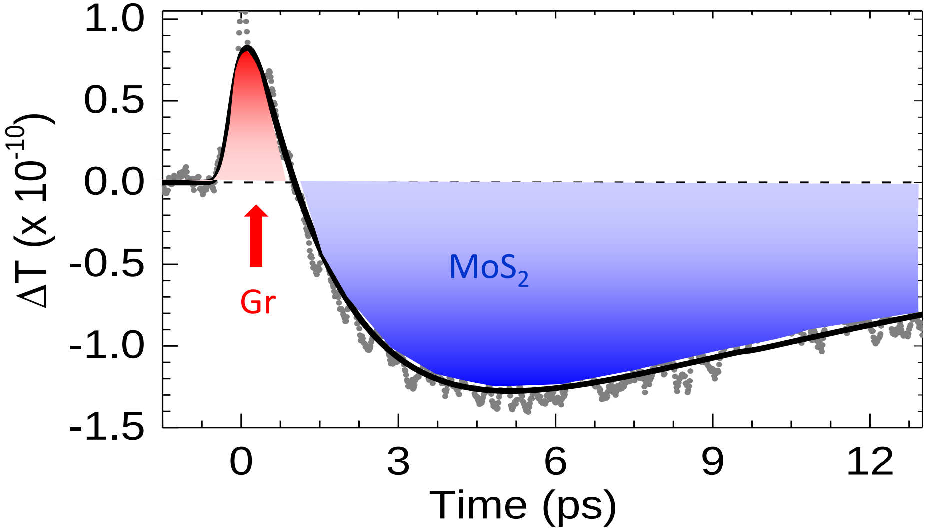
Optical pump – THz probe on $GrMoS_2Gr$

λ_p = 3.1 eV (0.4 µm)



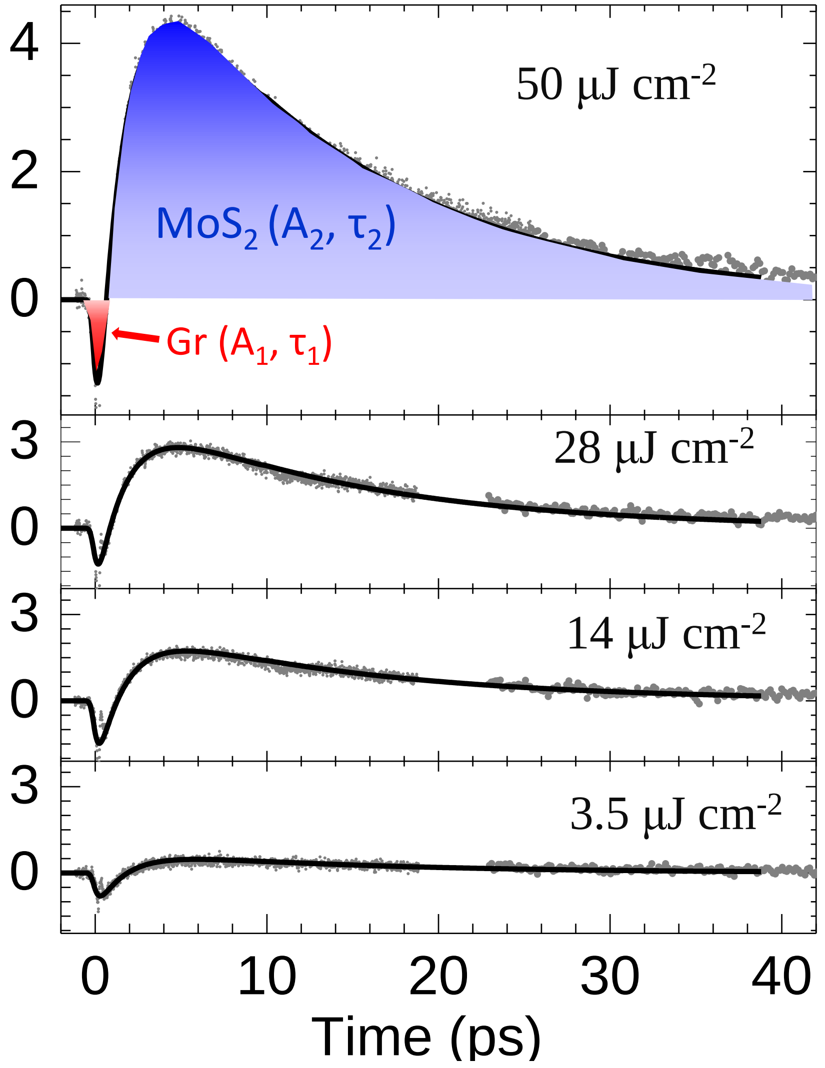
Exc @ 1.55 eV (800 nm)

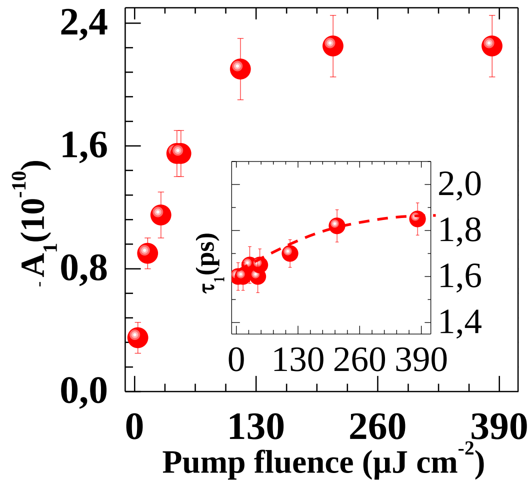




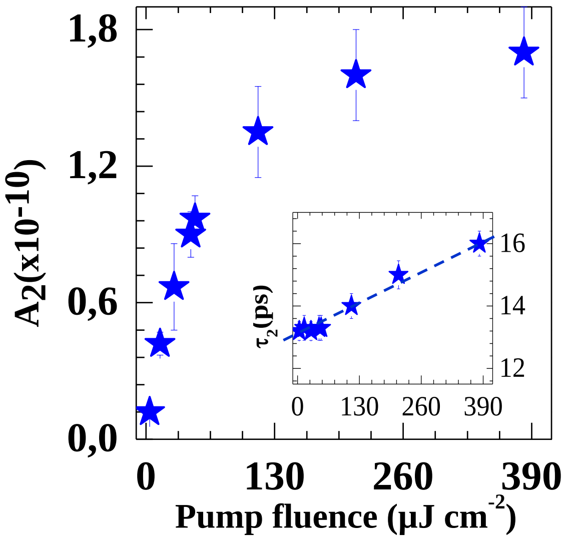
Spectroscopie pompe optique - sonde THz

Exc @ 1.55 eV





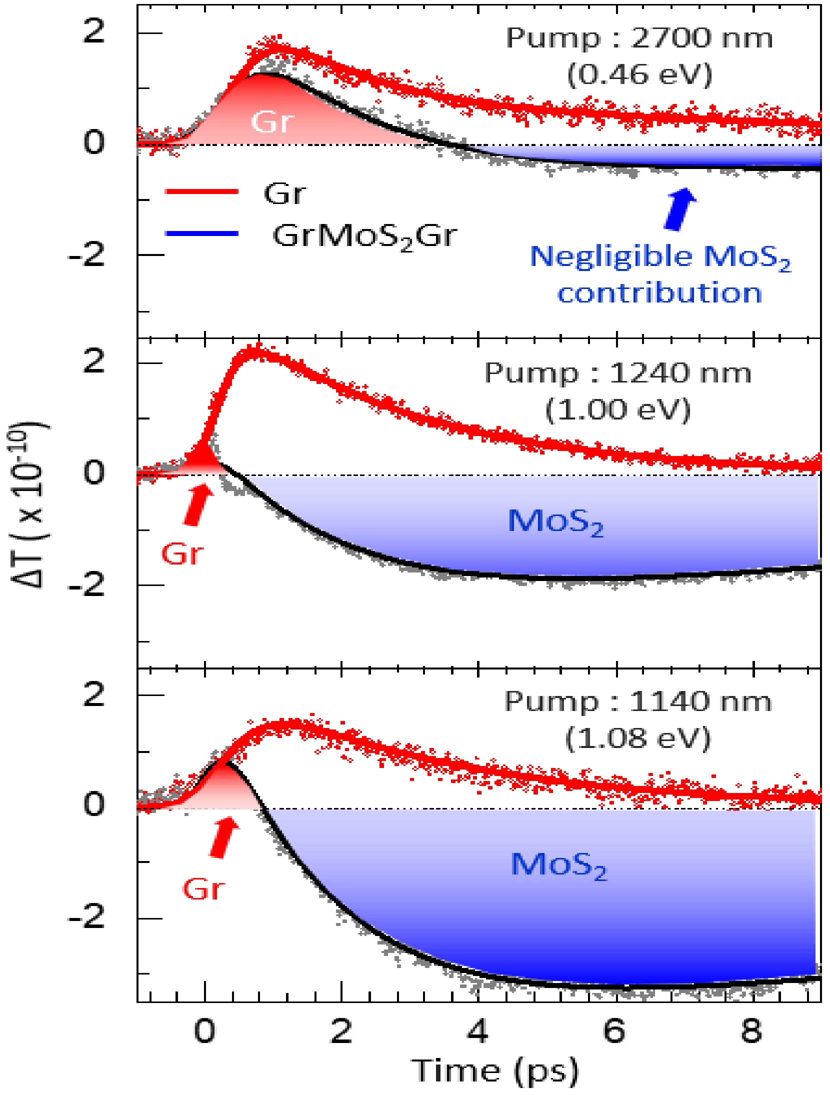
- Similar saturation intensity than graphene ~130 µJ. m^{-2}.
- Faster relaxation τ_1~1.8 ps instead of 3 ps



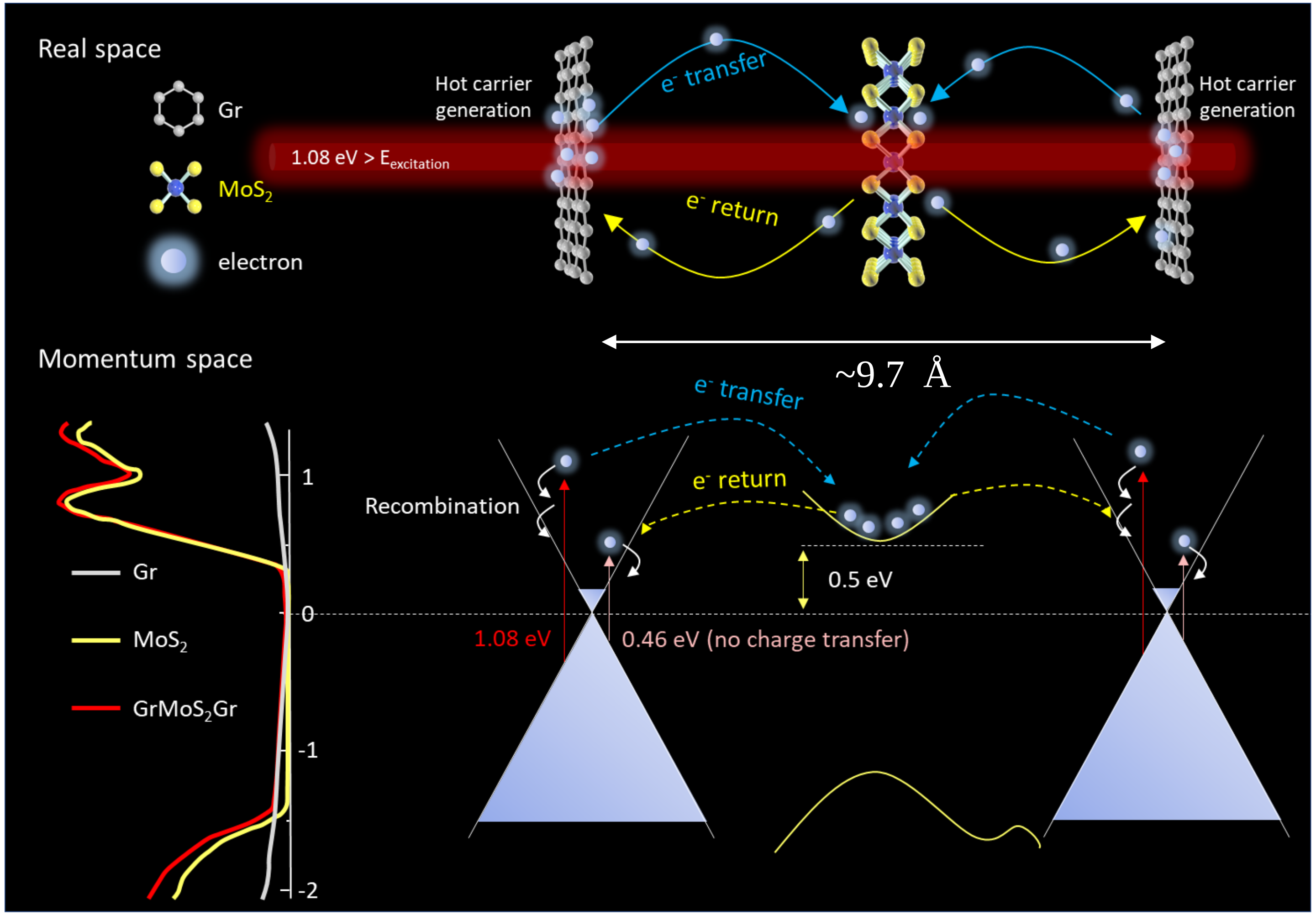
- Similar saturation intensity than graphene ~130 µJ. m^{-2}.
- Slower relaxation τ_2~15 ps instead of 12 ps than MoS_2.

Impact of the pump wavelength

Keeping a pump fluence of ~50 µJ.cm^{-2}



Mechanism in play



Ref: L. Shao, G. Chen, H. Ye, Y. Wu, H. Niu, Y. Zhu, *EPL* **2014**, *106*, 47003

Conclusions and prospects

- **We have prepared a Gr/MoS_2/Gr heterostructure and we characterized it by optical absorption, Raman Spectroscopy and THz-TDS spectroscopy.**

- **Optical and Raman spectroscopy indicates that even through the weak VdW interactions A, B exciton of MoS_2 as well as Raman modes of MoS_2 and Graphene are affected.**

- **The real part of the THz conductivity of the heterostructure resembles that of graphene. The small negative part of it imaginary part stresses the conductivity is likely describe by a Drüde-Lorentz model.**

- **Optical-pump THz-probe experiments performed in the heterostructure below the band gap of MoS_2 indicate that carriers generated in Graphene are likely rapidly transferred towards MoS_2.**

- **We have proposed a mechanism that account for this phenomena and evaluated to ~70% the number of carriers transferred from $MoSe_2$ to MoS_2.**

- **We have therefore demonstrate one can on demand rapidly switch, the THz conductivity of such heterostructures pumping then on a very broad spectral range.**

- **This phenomena is not peculiar to MoS_2 and it should happen using other semiconducting TMDC**