Polarimetric Raman instrumental development and Stress measurement application by using polarized Raman spectroscopy

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Scientific and technical objectives

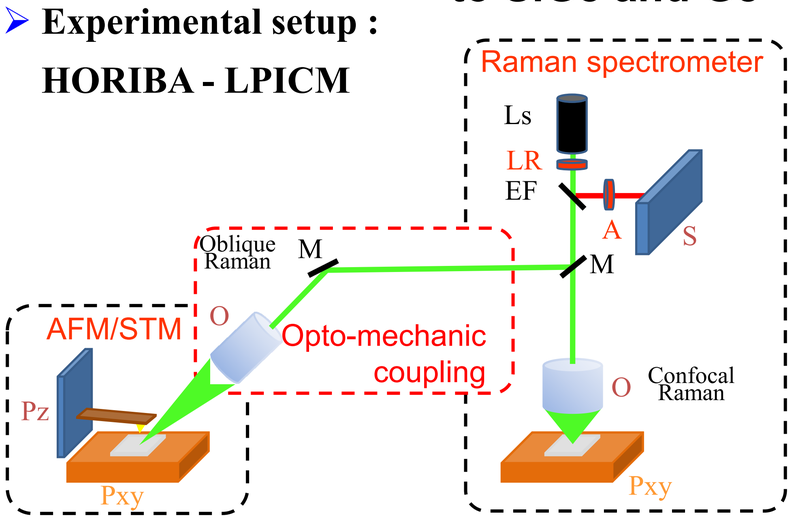
***CONTRAM*: Determining the stress tensor through spatially resolved polarimetric Raman spectroscopy**

- Polarimetric Raman spectrometer development (LPICM, HORIBA Jobin Yvon)
- Validation of the method by reference samples and techniques (LPICM, CEA-LETI)
- Applications in the stress characterization to innovative structures (LPICM, CEA-LETI)
- Applications in the stress characterization to semiconductor (Si, SiGe, Ge, GaAs…) and photonic structures (STM, 3SP, LPICM)

Stress measurement trough polarized Raman: from Si to SiGe and Ge

Experimental setup :

HORIBA - LPICM



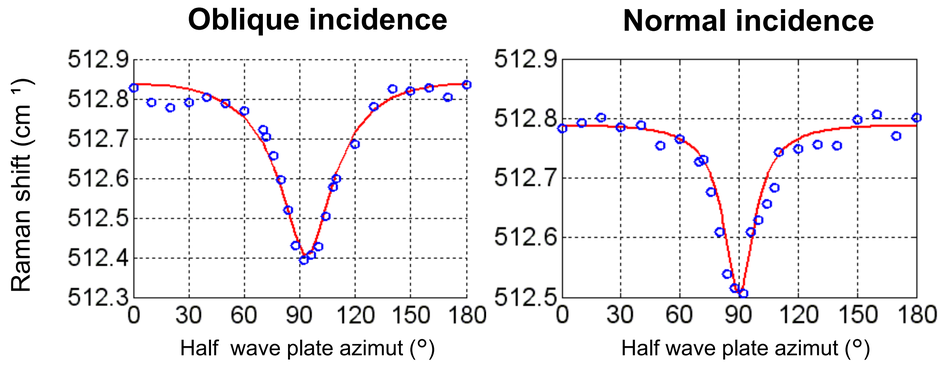
- Ls : laser
- FE : edge filter
- O : objective
- M : removable mirror
- LR : half wave plate
- A : Analyzer
- S : spectrometer
- Pz : z - piezo
- Pxy : xy - piezo

Samples and methodology of strain measurement

SiGe deposited on Si substrate

- Spectrum acquisition as function incident polarization orientation
- Determining of Raman shift
- Adjustment the results with the numerical model for strain or stress tensor identification

Results



$\sigma_{xx} = \sigma_{yy} = -041 \pm 0\,MPa$ $\quad\quad$ $\sigma_{xx} = \sigma_{yy} = -030 \pm 0\,MPa$

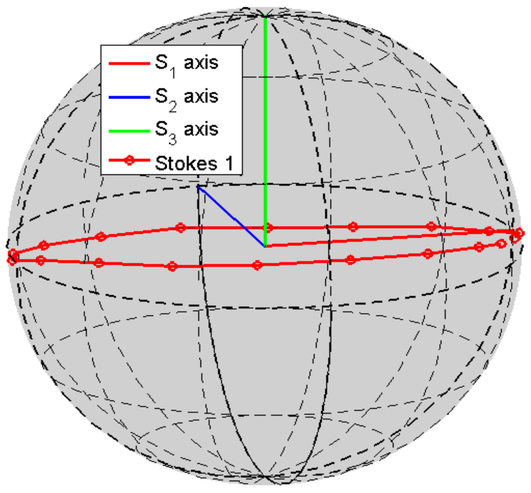
Oblique incidence → More accurate stress determination

From polarized Raman to polarimetric Raman…

Experimental methodology: polarimétric Raman calibration on Si band (521 cm^{-1})

To determine Stokes vectors (by Fourier Transform method) , we insert in the detection (scattering) path before the analyzer, a rotating quarter wave plate. From 36 measurements at different orientations of the plate, we can determine the backscattering Stokes vector

Real polarimetric response of the system in Raman scattering



Stokes vectors on Poincaré sphere for each orientation of P1

- Confocal Raman configuration
- λ = 514.5 nm
- Dop variation between 0.95 et 1
- Three components [S_1 , S_2 , S_3] constitute ellipse and no united circle

Presence of :
- Depolarization
- Diatténuation
- Birefringence

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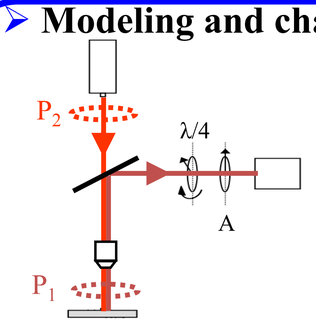
Modeling and characterization of the spectrometer response



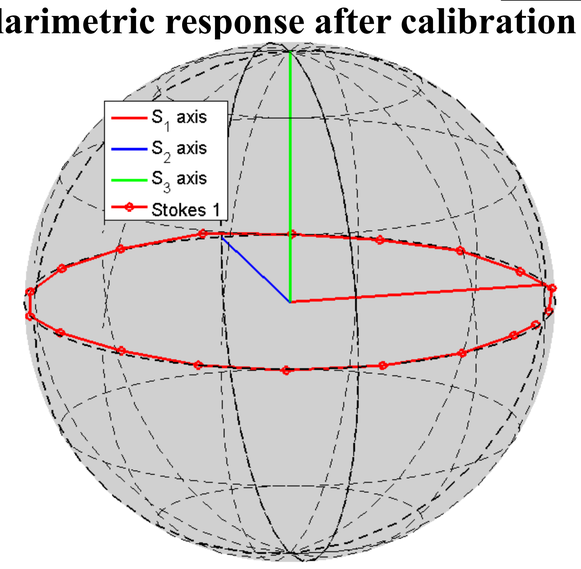
Model :
- Exciting path: $M_{exc} = M_\Delta . M_R . M_\Delta$
- Scattering path : $M_{det} = M_R . M_D . M_\Delta$

with :
- M_D : linear diattenuator Mueller matrix
- M_R : linear birefringence Mueller matrix
- M_Δ : depolarizing element Mueller matrix

1. Scattering path characterization :
- Rotating polarizer in position P_1 and measurement of the scattering Stokes vectors
- Determination of M_{det} from : $\min_{R,D,\Delta} \left\langle \left\| M_{det}^{-1} S_{mes} - S_{theo} \right\| \right\rangle$

2. Excitation path characterization :
- Rotating polarizer in position P_2 and measurement of scattering Stokes vectors
- Determination of M_{exc} from : $\min_{\Delta, D, R} \left\langle \left\| M_{exc}^{-1} M_{det}^{-1} S_{mes} - S_{theo} \right\| \right\rangle$

Polarimetric response after calibration



Stokes vectors on Poincaré sphere for each orientation of P1

Parameters of the model :

Excitation:

[Δ D R] = [0.987 0.0069 -6.91 °]

Scattering :

[R D Δ] = [10.88 ° 0.01 1]

Accuracy of the model:

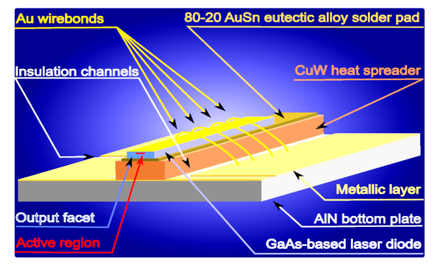
$\sigma_S = 10^{-2}[2.46 \quad 3.3 \quad 0.8]^T$

$\sigma_{Dop} = 0.0074$

Final calibration of the polarimetric Raman

Problems : Reducing the mechanical strain due to the transfer (deposition)

3S PHOTONICS RESULTS (with University of McMaster)



Samples

- High power laser diode **AlGaAs/GaInAs**
  Plain **AlN** or original bi-material **CuW/AlN**
- Lasts brazing in eutectic alloy **AuSn** [80-20 wt%]
- « *p-side up* » assembly
- Stress is due to the cooling of the assembly because of difference of thermal expansion coefficient and the dimensional disparities
- **Decreasing of the strain by bi-materials approach**

1. Theoretical approach: Modeling by finite element method (FEM)

- **3D thermo-mechanics** model
- Mechanicals properties of materials
- Simulation of brazing solidification
  ➔ cooling from **280°C to 20°C**
- Determining of the **Stress tensor**
  ➔ we show (σ_z - σ_x) (in Fig. 1)

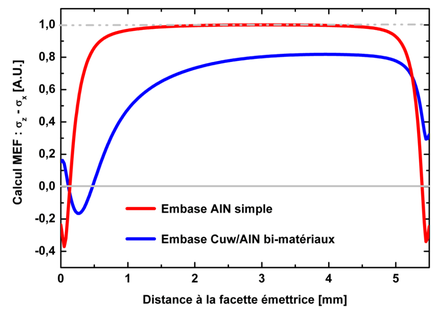


Figure 1 : *Résultats MEF*

2. Experimental approach : degree of polarization (DoP) measurement trough photoluminescence

- Photoluminescence emitted by superior face of the plan diode **AlGaAs/GaInAs**
- DoP is proportional to the difference of strain according to two axis of the studied plan
  ➔ $DoP = \frac{L_z - L_x}{L_z + L_x} = C_{sGa} \times (\sigma_z - \sigma_x)$

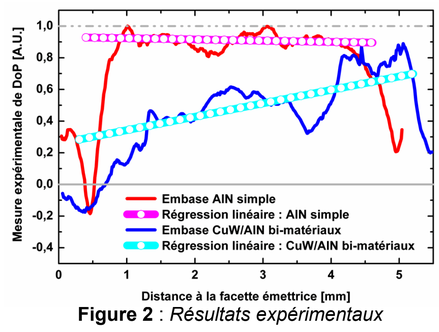


Figure 2 : *Résultats expérimentaux*

Results

- **FEM** : Reducing the stress level to **-20%**
- **DoP** : Reducing the stress level to **-46%**
- **Double side effect** on bi-material submount

Results to be confirmed in polarized or polarimetric Raman by LPICM

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