Can early–stage detection of pathogens in plants be enlighted by luminescent nanoparticles?

LightMyPath

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MOTIVATION

Grapevine Trunk Diseases (GTDs)

One of the **main causes of vine decline, threating the viability of viticulture**

Two of the main challenges are related to

The undetermined latency period, in which the plants **do not display visible external symptom.**

In nurseries, there is high cross-contamination risk of infected plant material **throughout the production process.**

Management strategies of GTDs

Preventive Cultural Practices (Prunning techniques, wound protection methods, sanitation protocols in plant production processes)

Diagnosis & Monitoring methods

Post-Infection Mitigation protocols (Remedial Surgery, application of active ingredients, re-grafting, trunk renewal, among others)

Molecular & Serological
⚠ Qualified personnel
🔧 Prepared installations

Remote Sensing
📷 Expensive
External symptoms expression
Indistinguishable signal of abiotic stress

💡 HOW CAN WE ENLIGHT EARLY-STAGE DETECTION OF GTDs?

Biosensing Technologies

Nanomaterials & Nanostructures

Biosensing Nanoprobes

Transducer
Persistent Luminescent Nanoparticles (PLNPs)

Biological recognition
Antibodies
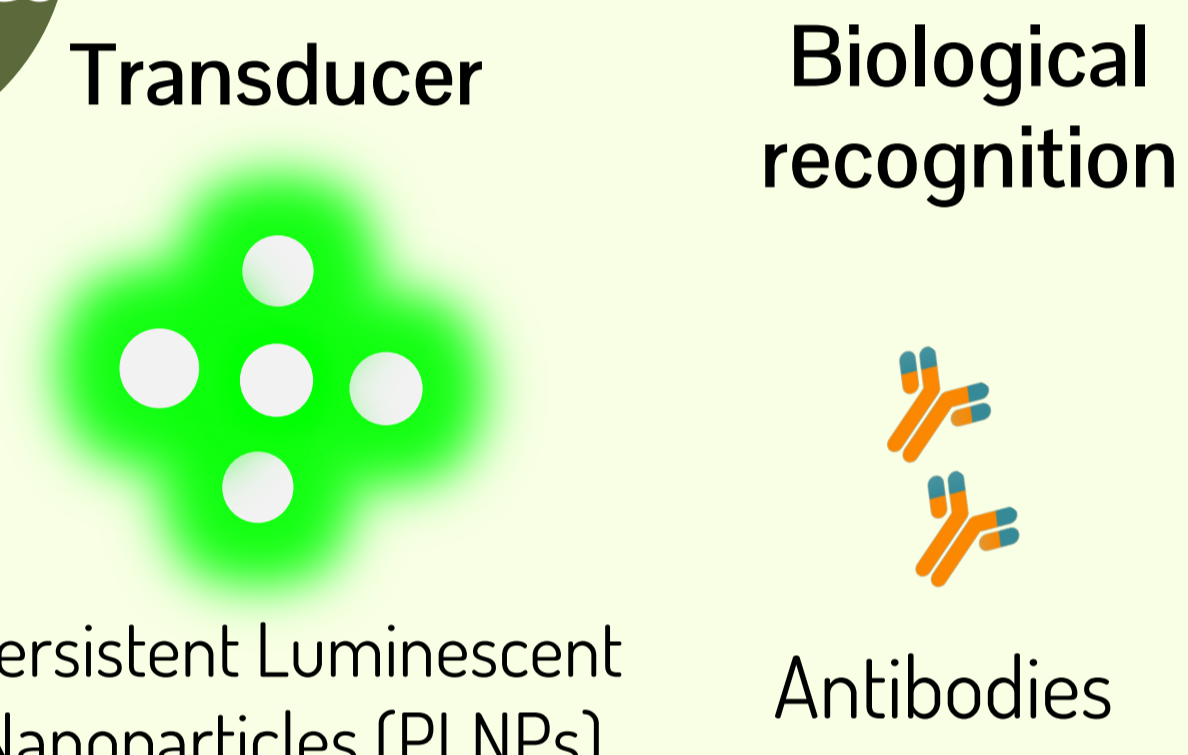
Targeting specifically

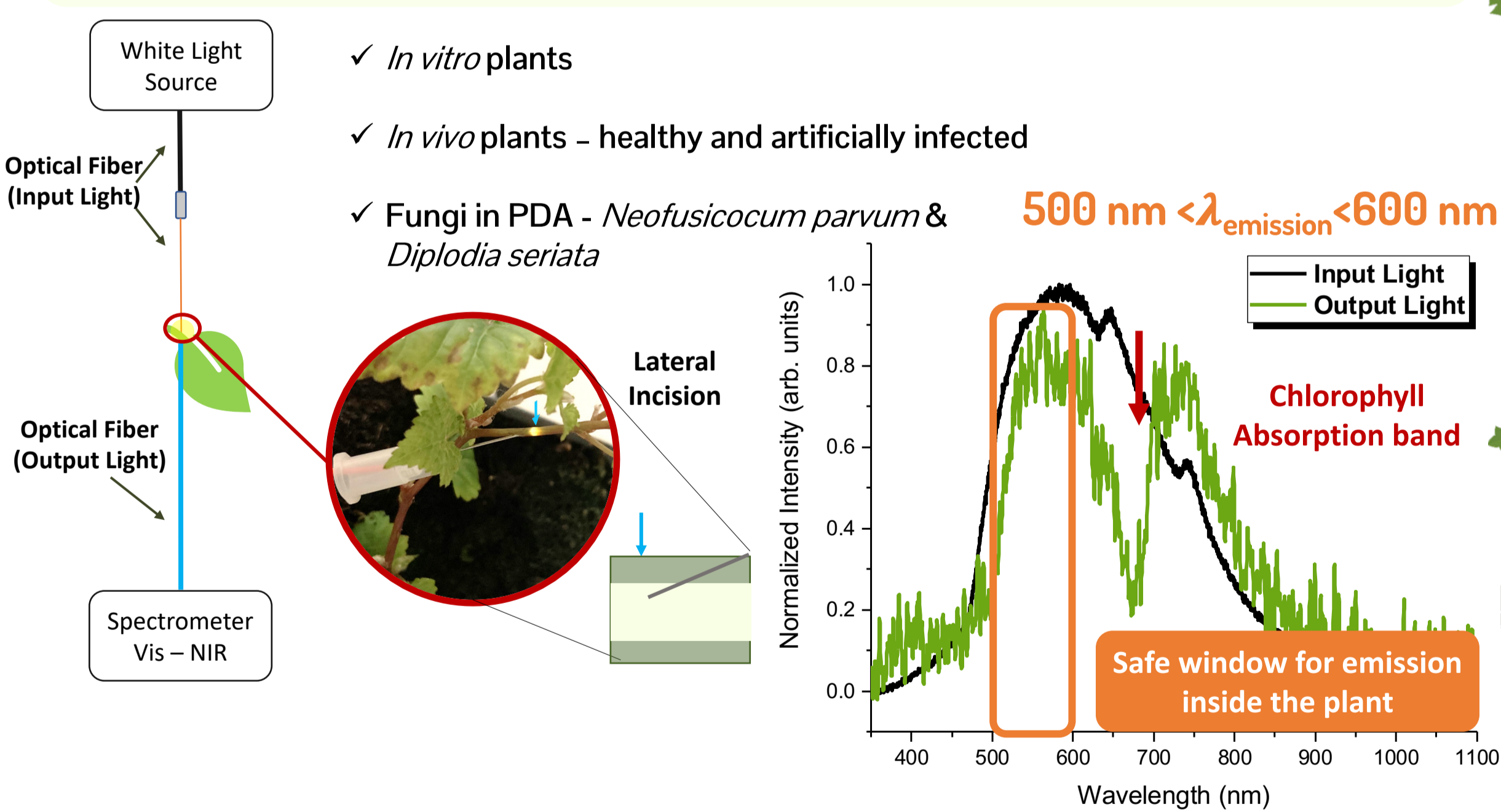**Analyte**
Botryosphaeriaceae family

In vivo Bioimaging

Biosensing Nanoprobes

✓ **Continuous and real-time** *in vivo* monitoring, providing a "**map**" of the disease in the plant

✓ Analysis through off the shelf equipment or by remote sensing technologies.

✓ Enables a **more effective application of mitigation protocols**

✓ It can be a crucial tool to **prevent cross-contamination of infected plant material** throughout the production process.

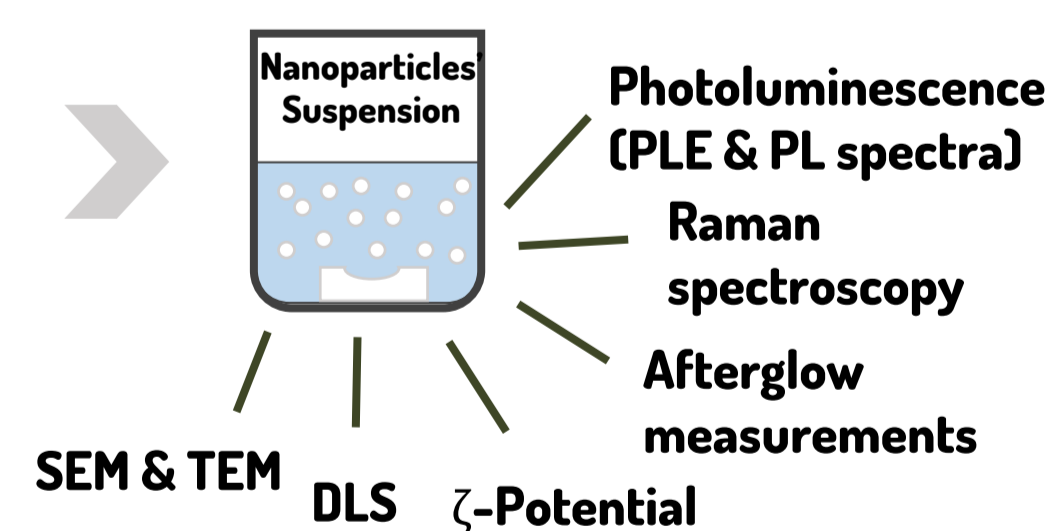## Synthesis and Characterization of Persistent Luminescent Materials

✓ **Assessment of Grapevine's stem tissues Light Transparency Window**

White Light Source
Optical Fiber (Input Light)
Optical Fiber (Output Light)
Spectrometer Vis – NIR
Lateral Incision

- *In vitro* plants
- *In vivo* plants – healthy and artificially infected
- Fungi in PDA - *Neofusicocum parvum* & *Diplodia seriata*

$500\ nm < \lambda_{emission} < 600\ nm$

Input Light
Output Light
Chlorophyll Absorption band
Safe window for emission inside the plant

☐ **Synthesis and Characterization of Persistent Luminescent powders and pellets**

Zn_2SiO_4 doped with Mn^{2+}

- **Solid–State Reaction (SSR)**
ZnO SiO₂ Mixing via ball milling Pressing Sintering of pellets ⚠1300°C

Raman spectroscopy

- **Solution Combustion Synthesis (SCS)**
$Zn(NO_3)_2$ Urea TEOS Magnetic stirring Gel formation & evaporation of solvents Combustion ⚠300–500 °C Pressing

Afterglow analysis

Photoluminescence (PLE & PL spectra)

Preparation of Functional PLNPs

☐ **Preparation of Nanoparticles via Pulsed–Laser Ablation in Liquid (PLAL)**

Main parameters and conditions to test:
- ✓ Laser wavelengths
- ✓ Pulse frequency
- ✓ Beam (de)focusing
- ✓ Liquid volume
- ✓ Solvent Nature
- ✓ pH
- ✓ Stabilizing Agents
- ✓ Ionic Strengths

Nanoparticles Suspension

Photoluminescence (PLE & PL spectra)
Raman spectroscopy
Afterglow measurements

SEM & TEM   DLS   ζ-Potential

☐ **Functionalization of Nanoparticles (NPs)**

Targeting specifically

Neofusicocum parvum *Diplodia seriata*
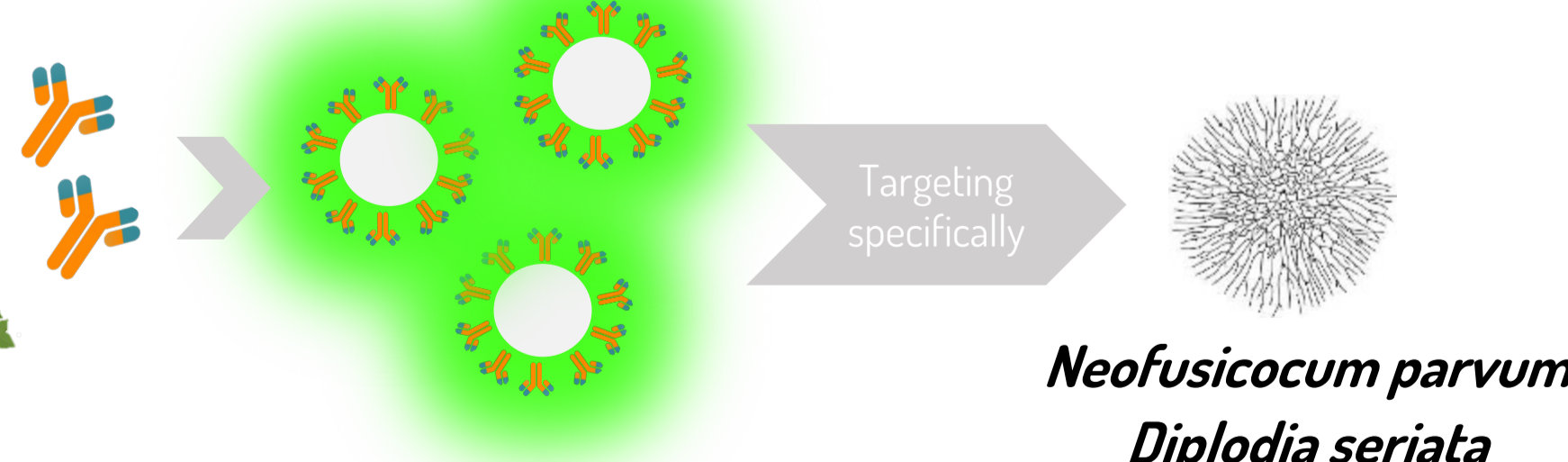
Main goals to accomplish:
- ✓ Acquire antibodies specific to the targets
- ✓ Develop protocol for immobilization of the antibodies into the surface of the NPs

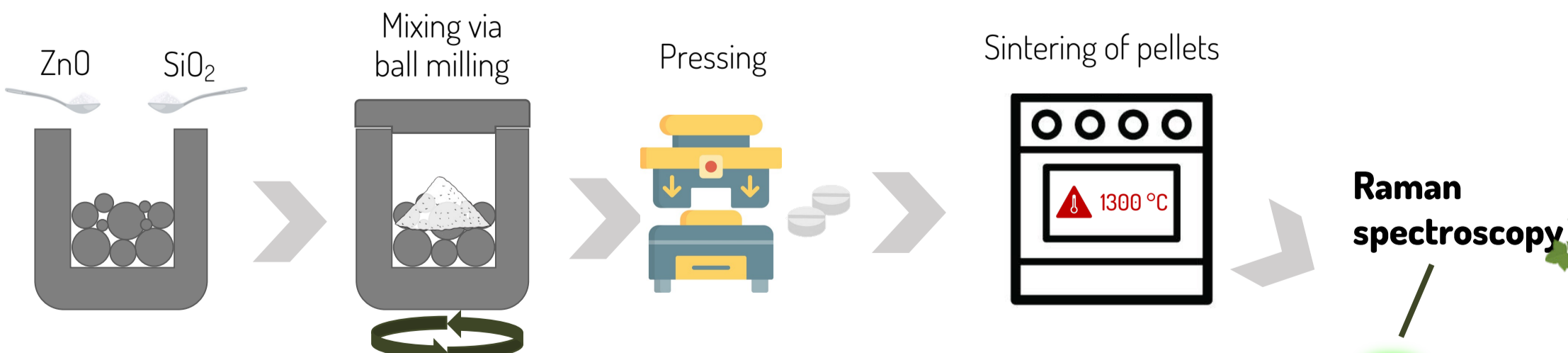## Application in *in vivo* Bioimaging

☐ **Application and evaluation of PLNPs in plants: *in vitro* and *in vivo***

For evaluation of *in-planta* interactions:
- ✓ Mechanism of NPs' uptake (stem injection, leaf spraying)
- ✓ Transport of the NPs throughout the plant
- ✓ Toxicity of NPs towards the plant
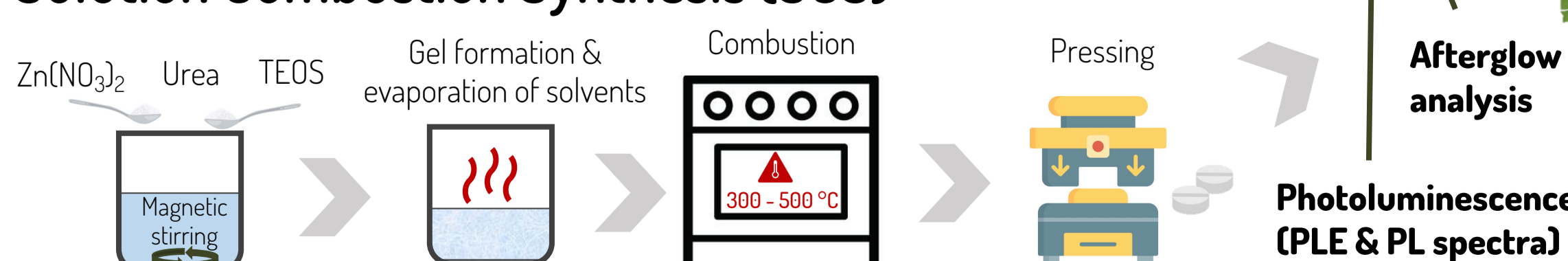- ✓ Specificity and sensibility of the NPs response

TAKE HOME MESSAGE

✓ **Detecting and diagnosing plant diseases promptly is crucial for effective crop management and food security,** especially when dealing with deadly pathogens that **cause significant losses and economic damage;**

✓ Early-stage detection of pathogens is critical, and **nanotechnology-based biosensing technologies can offer promising solutions** for crop management, quality and viability analysis of infection in the plants;

✓ **Luminescent nanoparticles** provide enhanced sensitivity and depth, making them **valuable for bioimaging and real-time monitoring.**

Acknowledgements