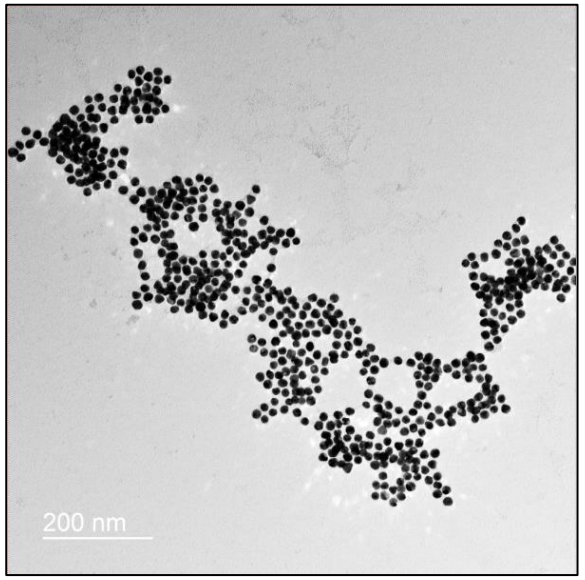
Evaluating the Infectivity and Prognosis of a Virion Sample using Plasmonic Nanoparticles and MATLAB Programming

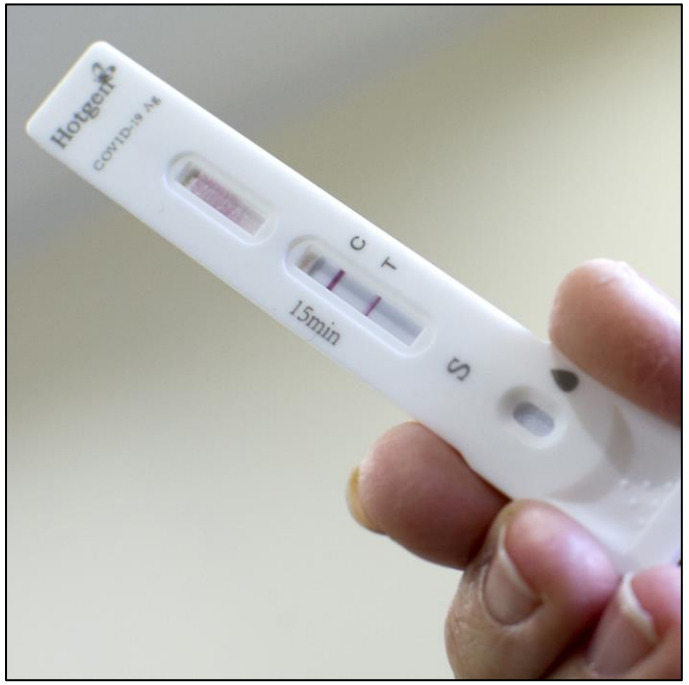


Bryan Hong

Status Quo

2 Standards of testing:

Nucleic Acid Test



Antigen Test

- **Nucleic Acid Test advantages:** Accurate, sensitive
- **Nucleic Acid Test disadvantages:** Resources, slow

- **Antigen Test advantages:** Rapid, cheap
- **Antigen Test disadvantages:** Not as sensitive, false-positives

Status Quo

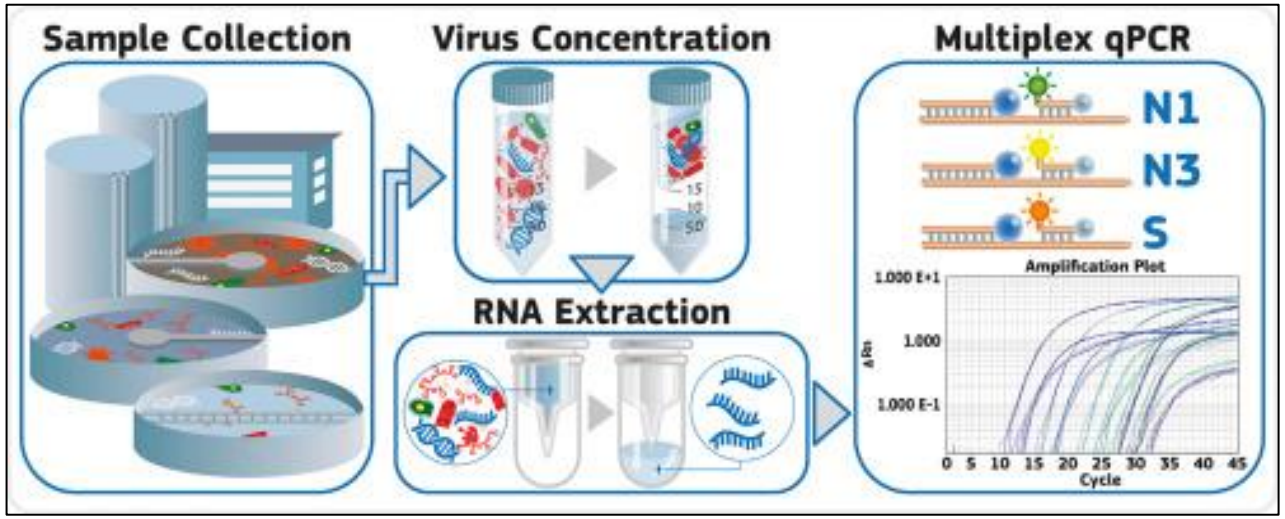
Viral Load Quantification:

- Method of counting virions present within a nasal swab

- Predicts the prognosis, infectibility, and severity of the viral sample

- Conducted using **Cycle Threshold Values** via PCR tests

Figure created by Tyson Holmes, 2021



- Counts the number of viral amplification steps before the virus is detected by the PCR test

- **Contains many issues**

Engineering Goals

I. Develop a rapid, sensitive, and accurate RSV diagnostic test that combines the advantages of both the antigen test and the nucleic acid test

II. Create a viral load quantification system that counts and displays the individual number of virions

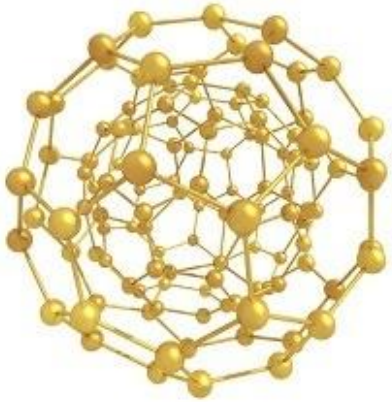
Principals and Procedures

I. RSV AuNP antibody aggregation

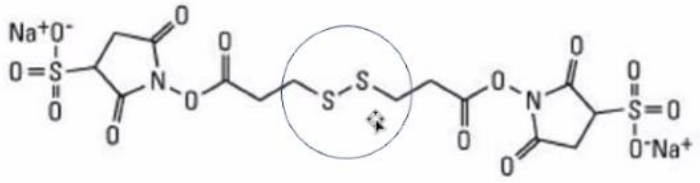
II. Nanobubble detection

III. Virion counting mechanism

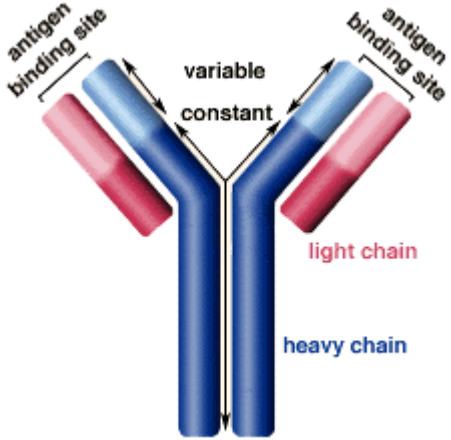
Principal I- AuNP Antibody Conjugation



Gold Nanoparticle (AuNP)



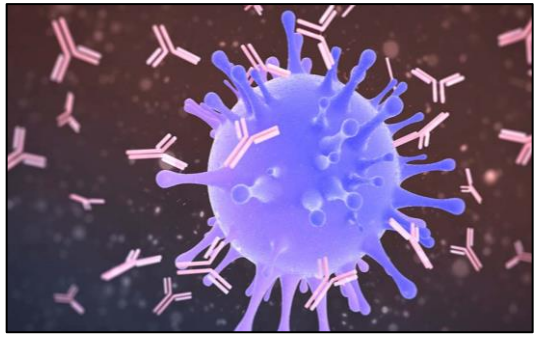
DTSSP Crosslinker



Palivizumab Monoclonal Antibody

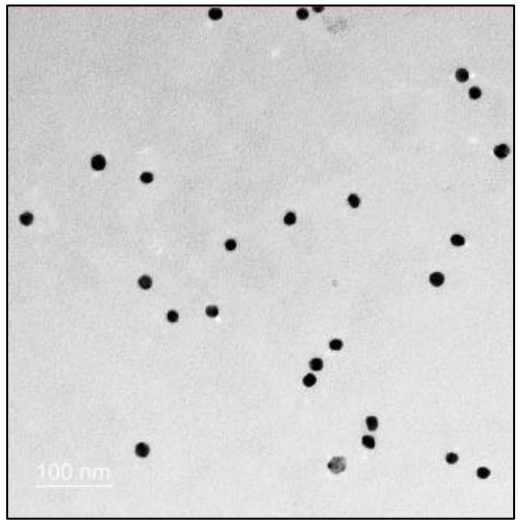
Principal I- RSV AuNP Aggregation

Figure created by Joseph Horus, 2020

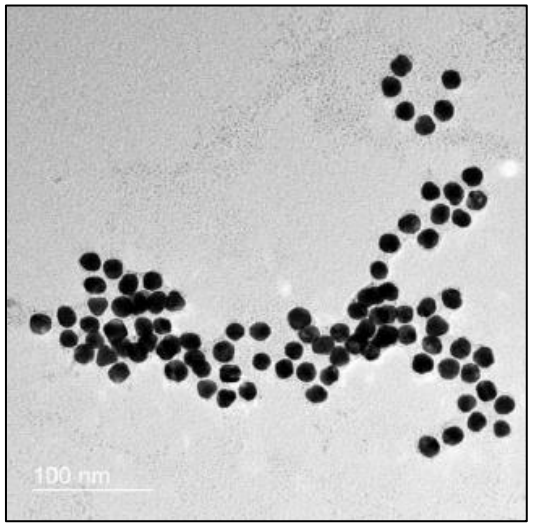


Palivizumab Antibodies binding to the F-glycoproteins on the RSV Virus

One virion has multiple AuNPs attached to it

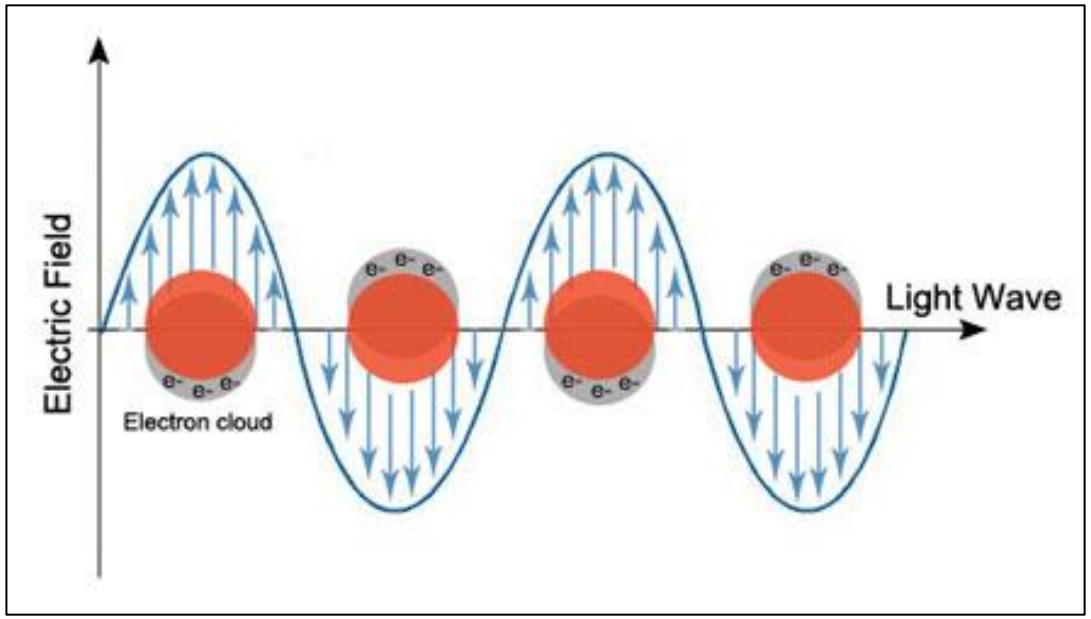


Unaggregated AuNP-Antibodies



RSV-aggregated AuNP-Antibodies

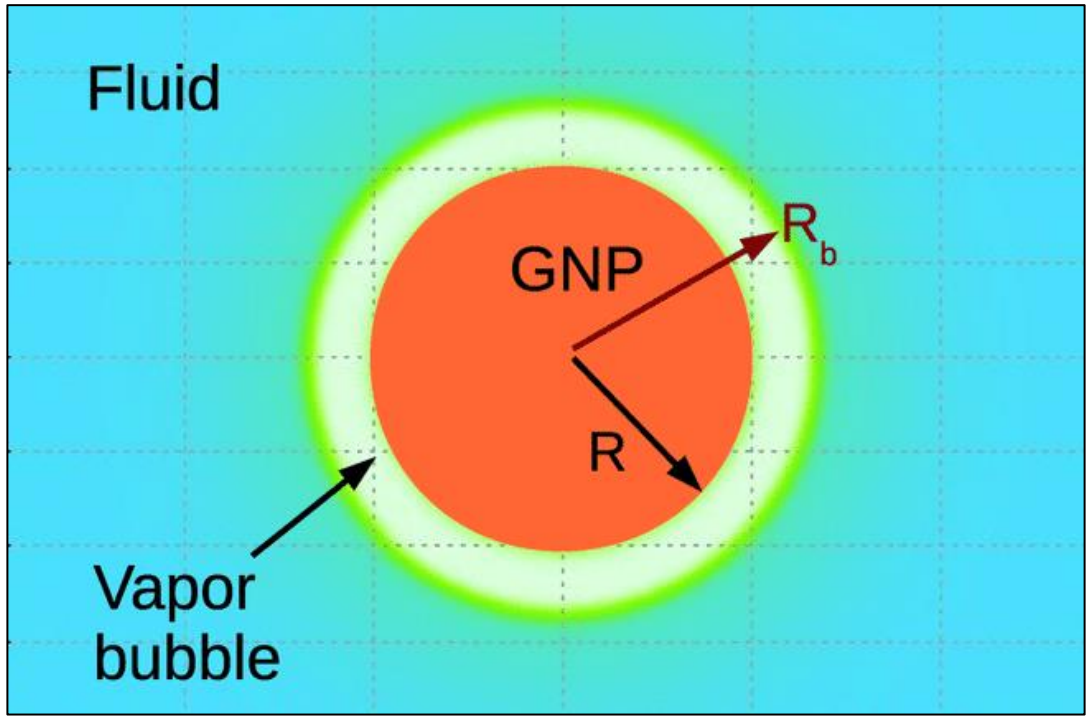
Principal II- Nanobubble Detection



Specific light wavelength will cause electrons on NP to oscillate → **Plasmon Resonance**

Plasmon Resonance for 15 nm AuNP = 532 nm (green light)

Principal II- Nanobubble Detection

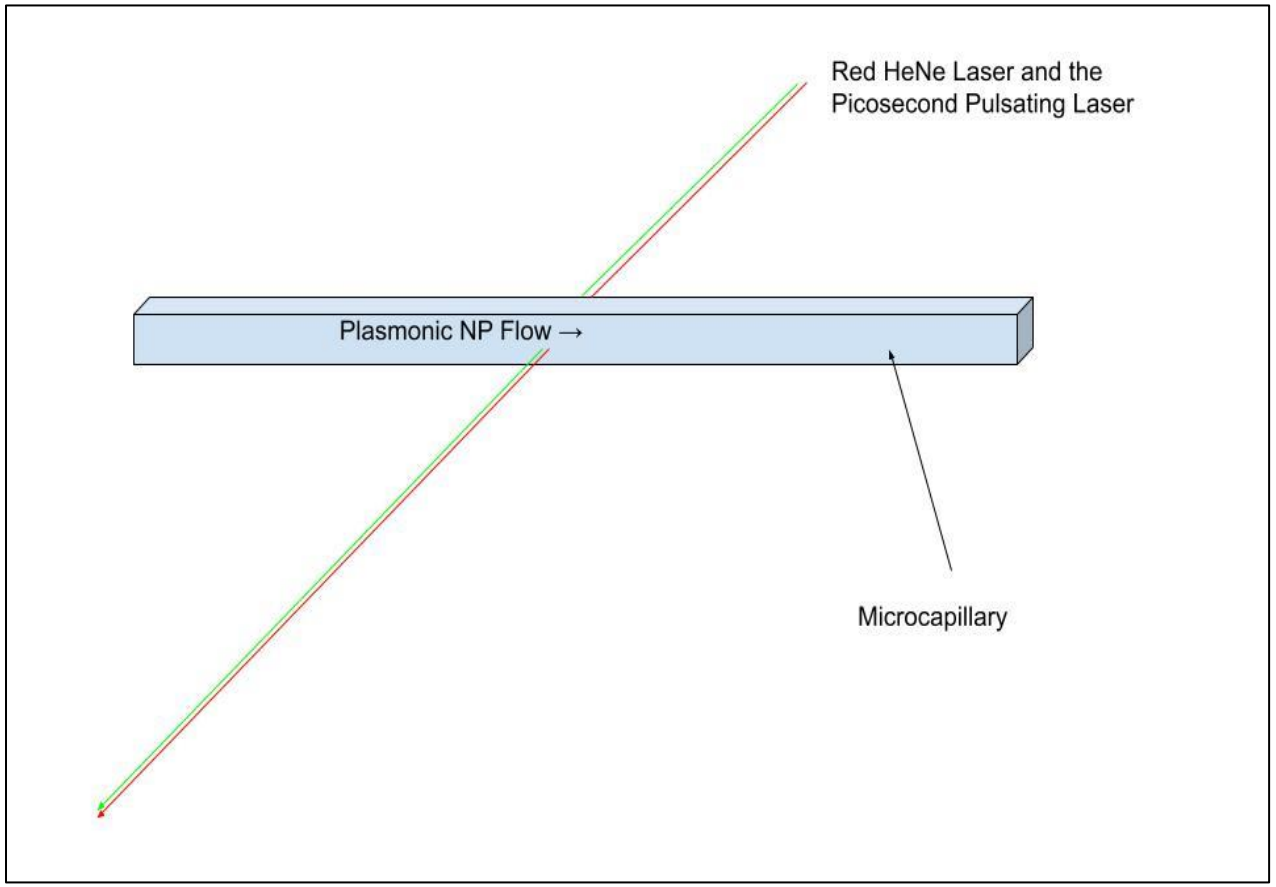


When the electrons oscillate on the AuNP, the AuNP heats up fluid around it → **nanobubble**

Using a red HeNe laser to detect **nanobubble**

Figure created by Jackson Martin, 2019

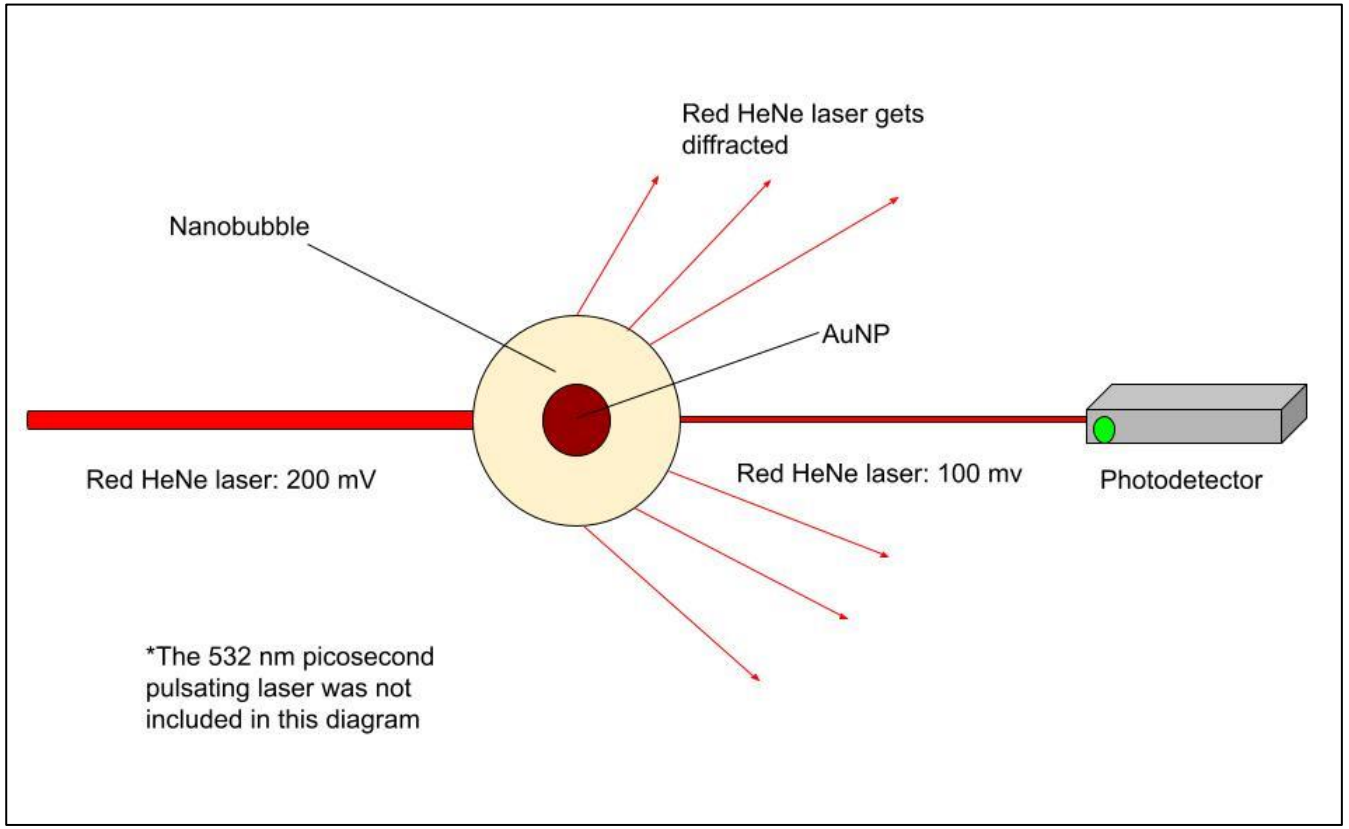
Procedure II- Nanobubble Detection



Step 1:

- Green picosecond pulsating laser → energizes the AuNPs → generates **nanobubbles**
- Red HeNe laser → detects the **nanobubbles**

Procedure II- Nanobubble Detection



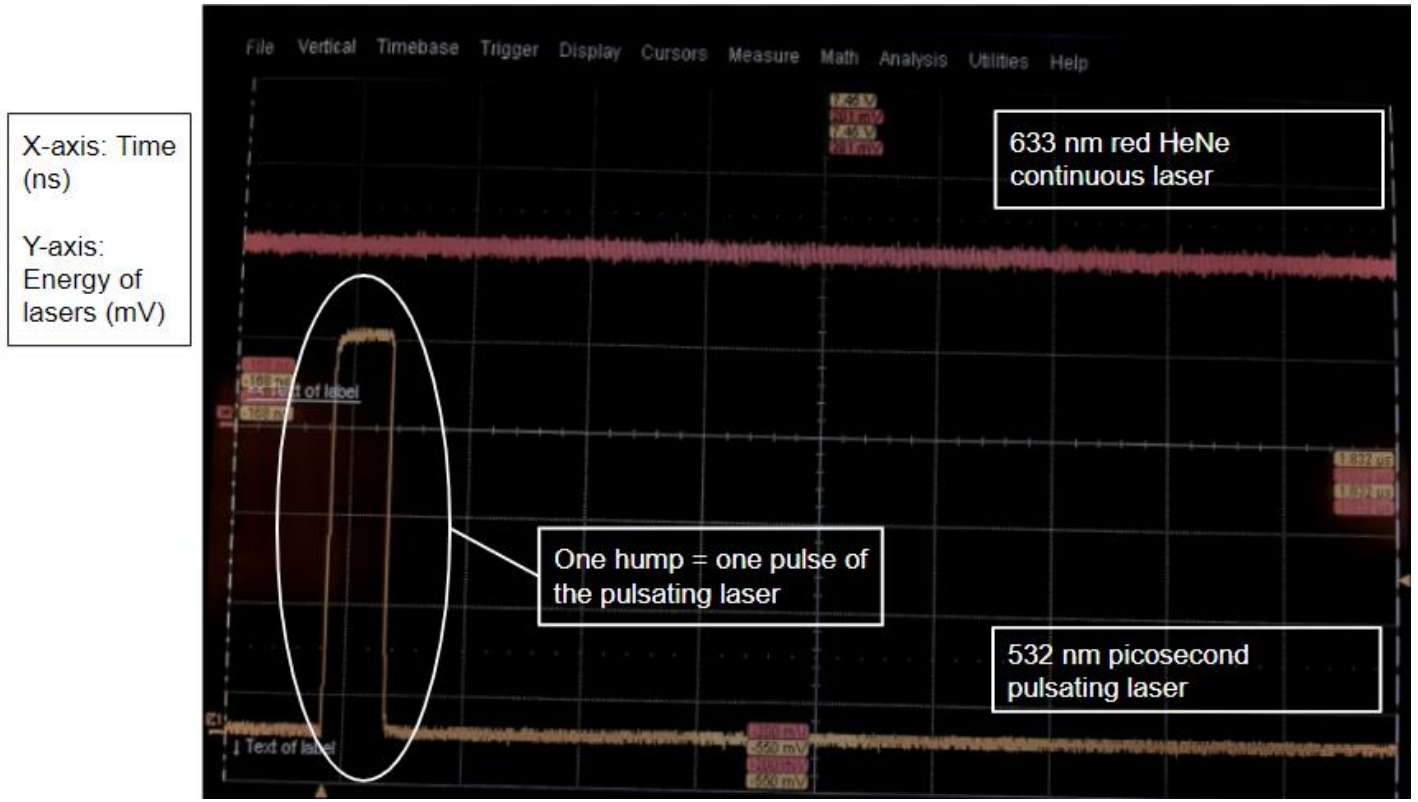
Step 2:

- Red HeNe laser diffracted by the **nanobubble**
- Laser energy decreases

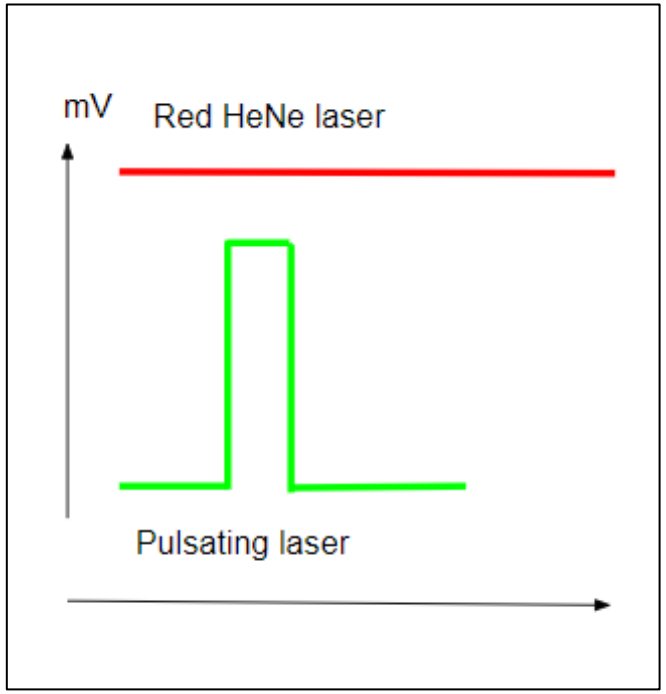
Procedure II- Nanobubble Detection

Step 3:

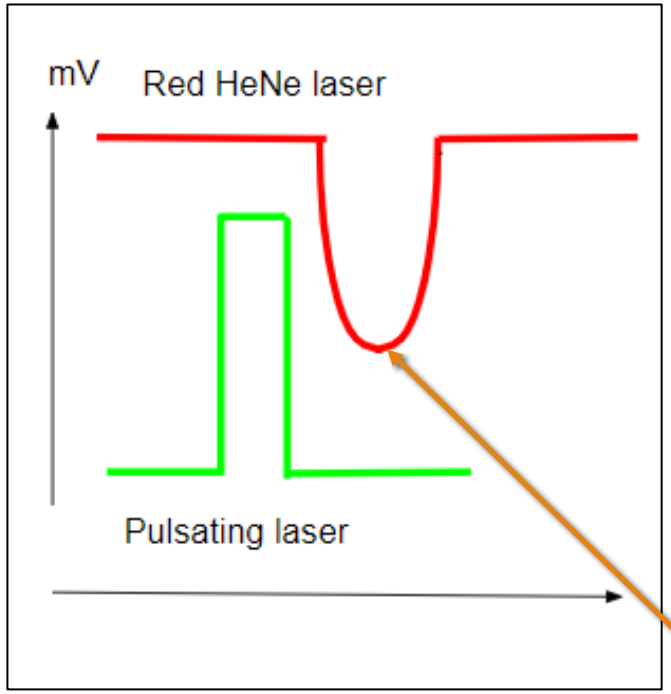
- Displayed onto the **oscilloscope**



Procedure II- Nanobubble Detection



No **nanobubble** detected



Nanobubble detected

Nanobubble detected → laser energy decreases

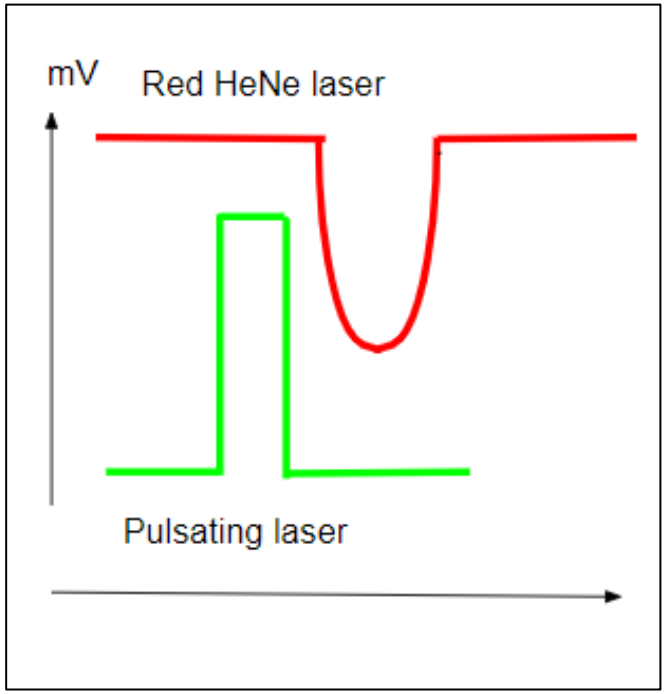
Principal III- Virion Counting System

I. Larger AuNP **aggregates** → larger **nanobubbles**

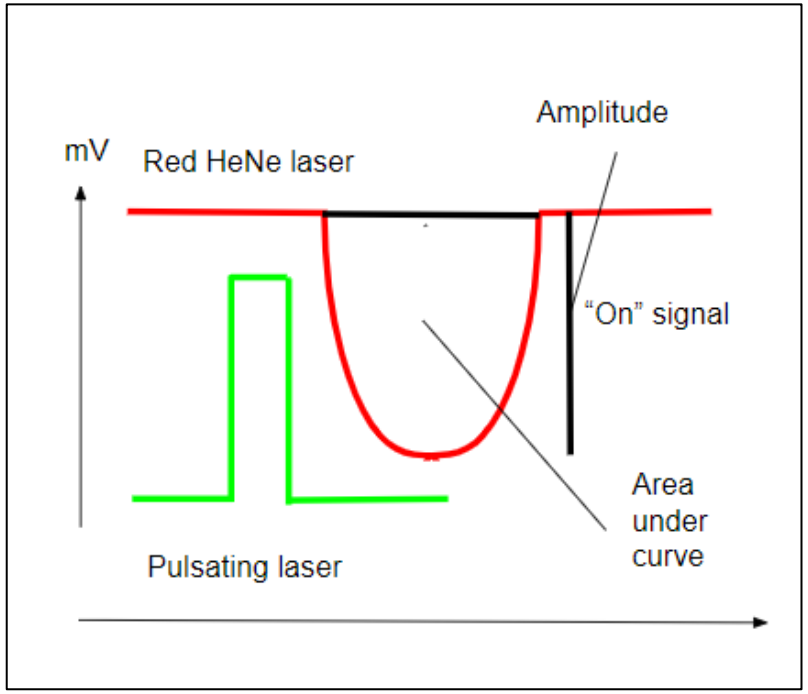
II. Larger **nanobubbles** → more laser diffraction

Procedure III- Virion Counting System

Off signal

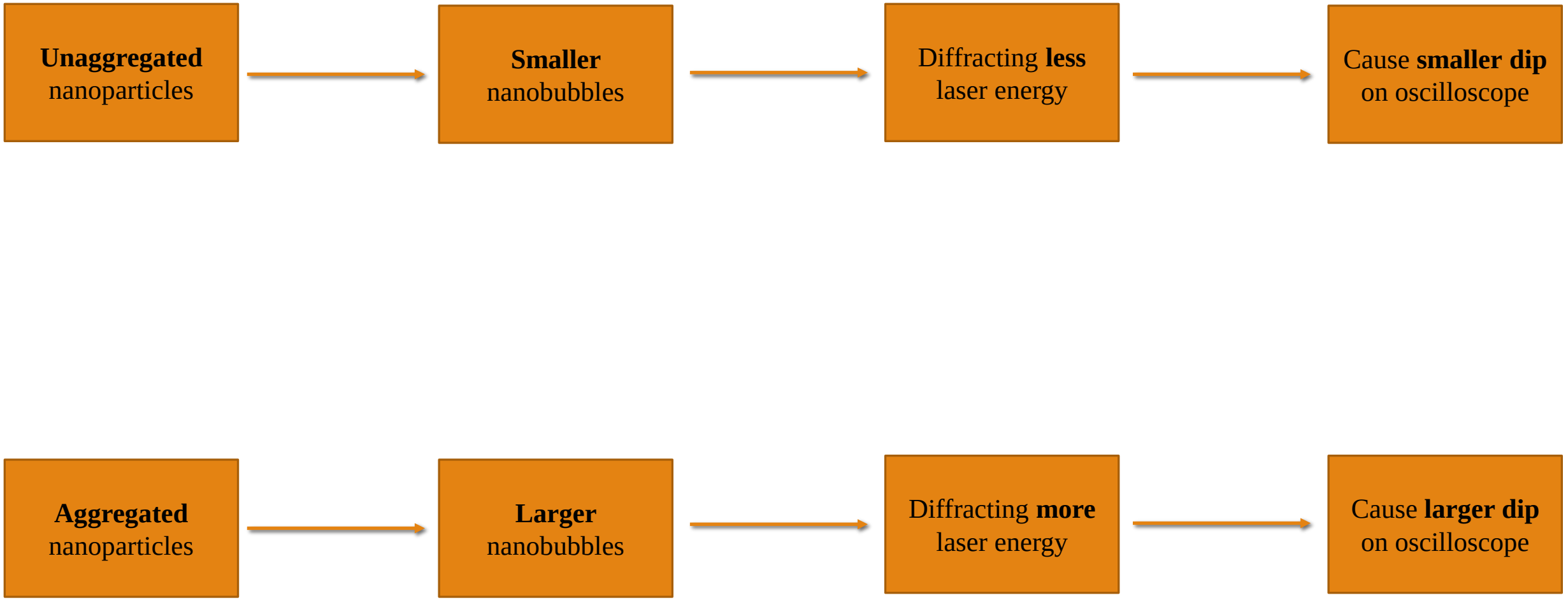


Unaggregated **Nanobubble** detected



On signal

RSV-aggregated **Nanobubble** detected


Unaggregated nanoparticles
Smaller nanobubbles
Diffracting **less** laser energy
Cause **smaller dip** on oscilloscope
Aggregated nanoparticles
Larger nanobubbles
Diffracting **more** laser energy
Cause **larger dip** on oscilloscope

Procedure III- Virion Counting System

Step 1:

- Feed the **unaggregated AuNPs** through the microcapillary and record amplitude and AUC of every signal
- Establishes the **threshold**

Threshold = $\mu+5\sigma$

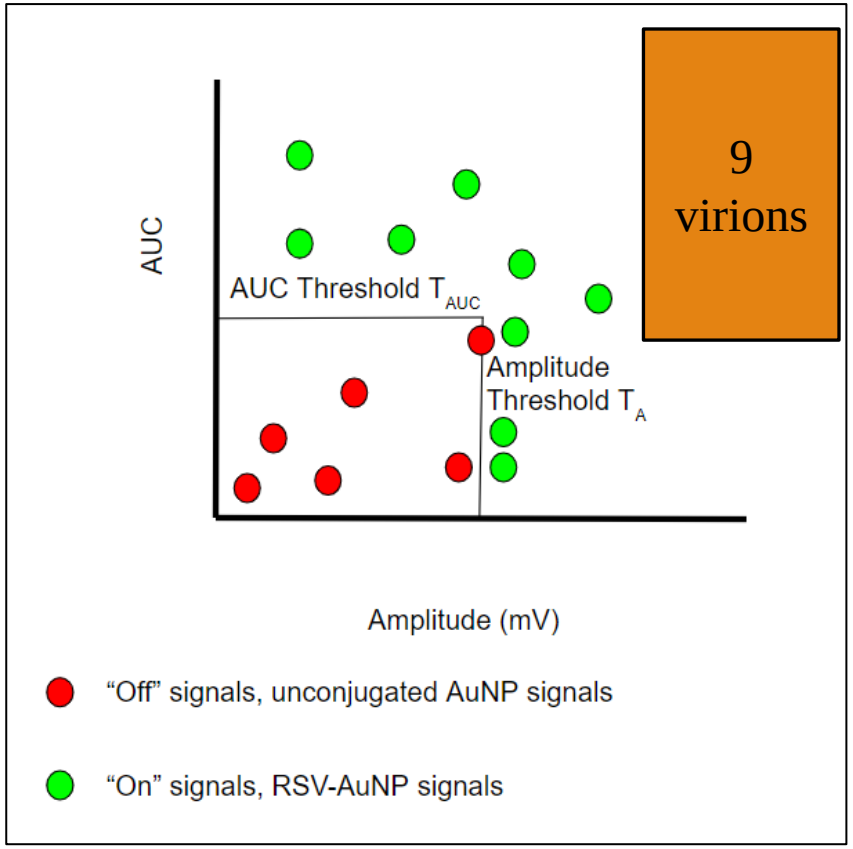
Amplitude threshold (T_{AMP})

AUC threshold (T_{AUC})

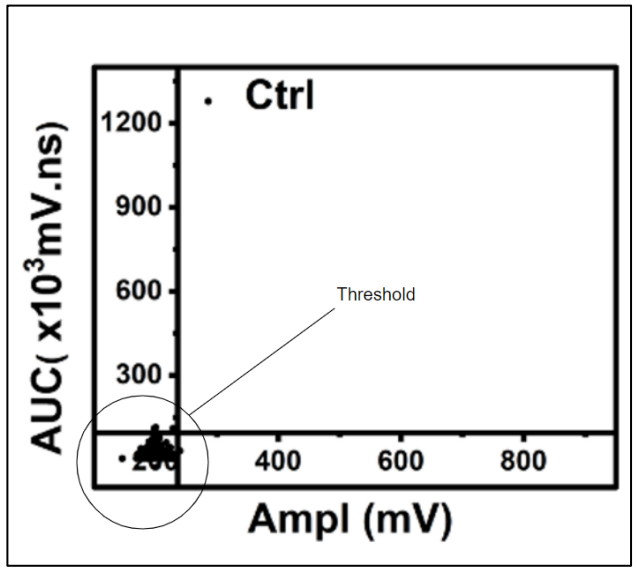
Procedure III- Virion Counting System

Step 2:

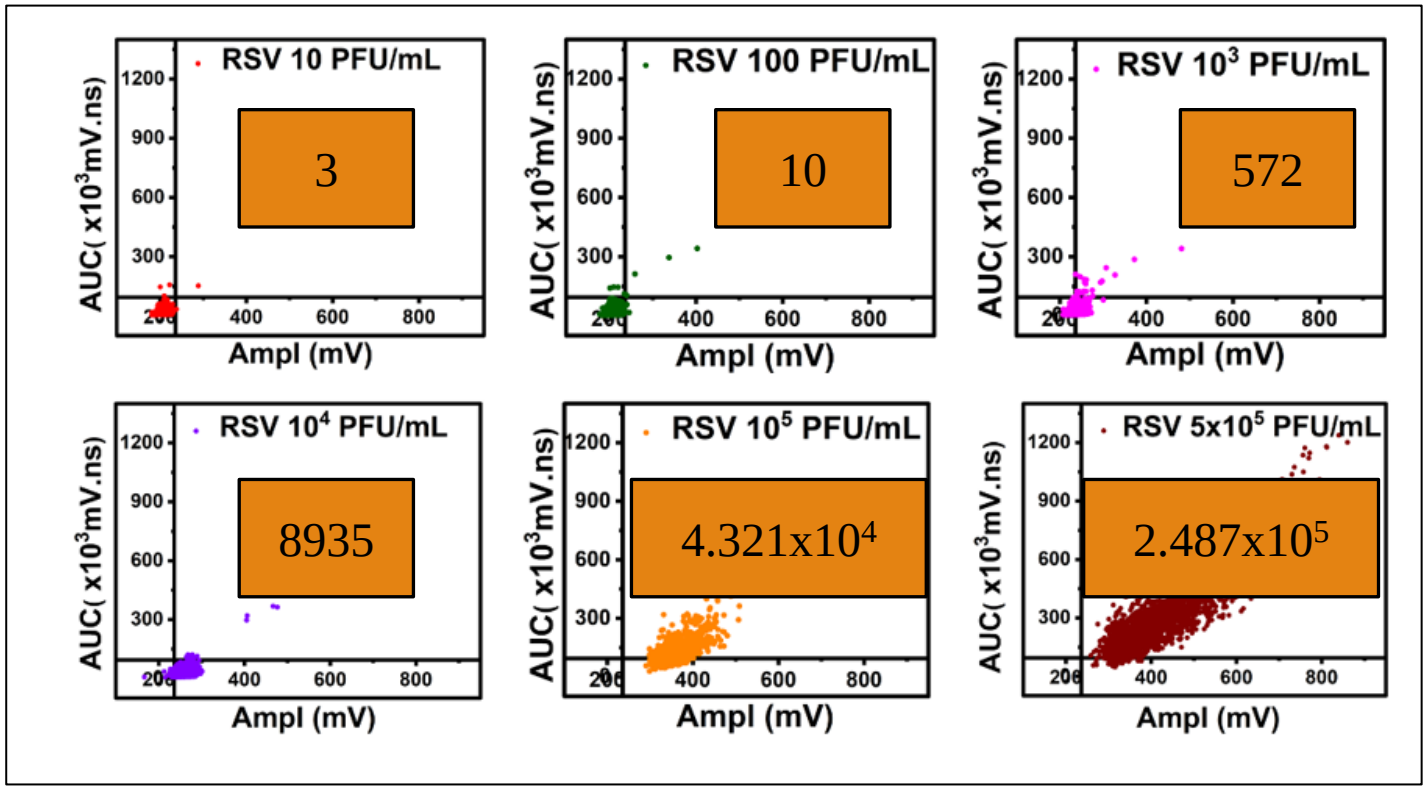
- Feed the **RSV-aggregated AuNPs** into the microcapillary
- Record amplitude and AUC of every signal
- > T_{AMP} or T_{AUC} → counted RSV virion



Results



T_{AMP} = 225.65
T_{AUC} = 137.13



Conclusions

I. Develop a rapid, sensitive, and accurate RSV diagnostic test that combines the advantages of both the antigen test and the nucleic acid test

- Generated results → avg 5.2 mins
- Accuracy +/- → 99.99%

II. Create a viral load quantification system that counts and displays the individual number of virions

- Results can be cross-validated using **Poisson Statistics**

Impacts

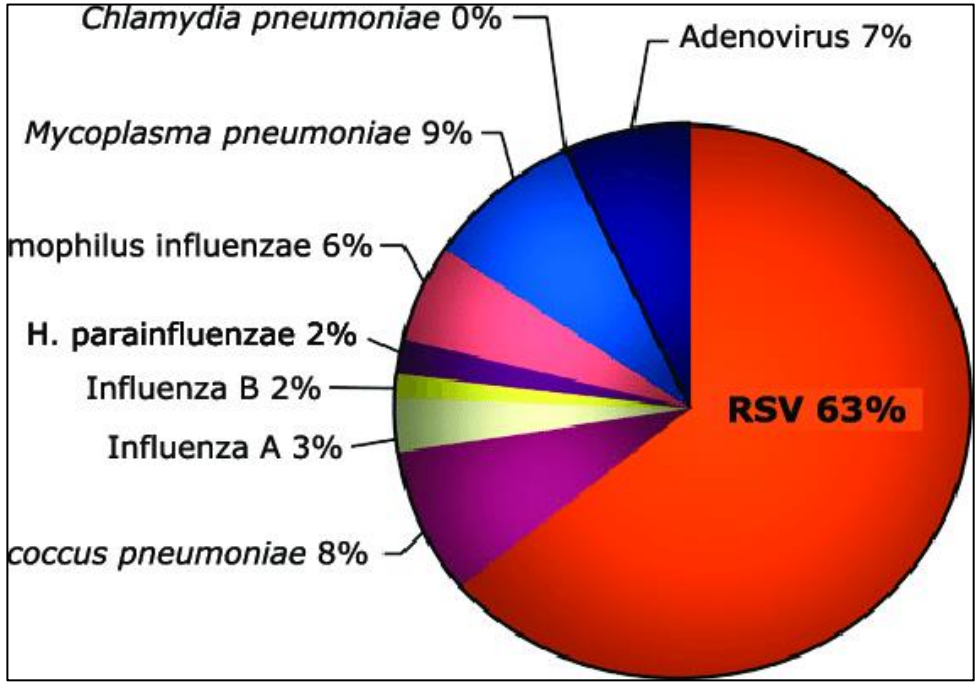
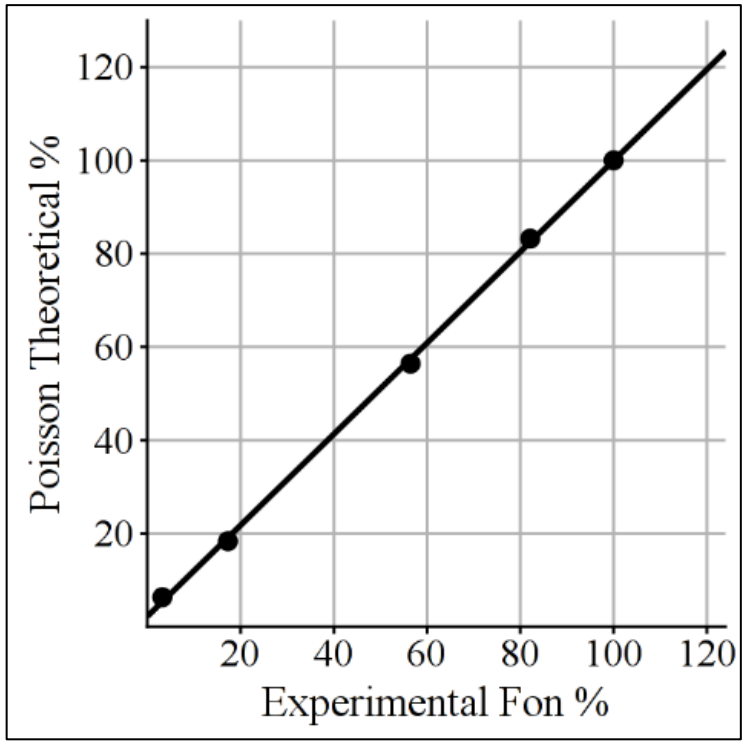
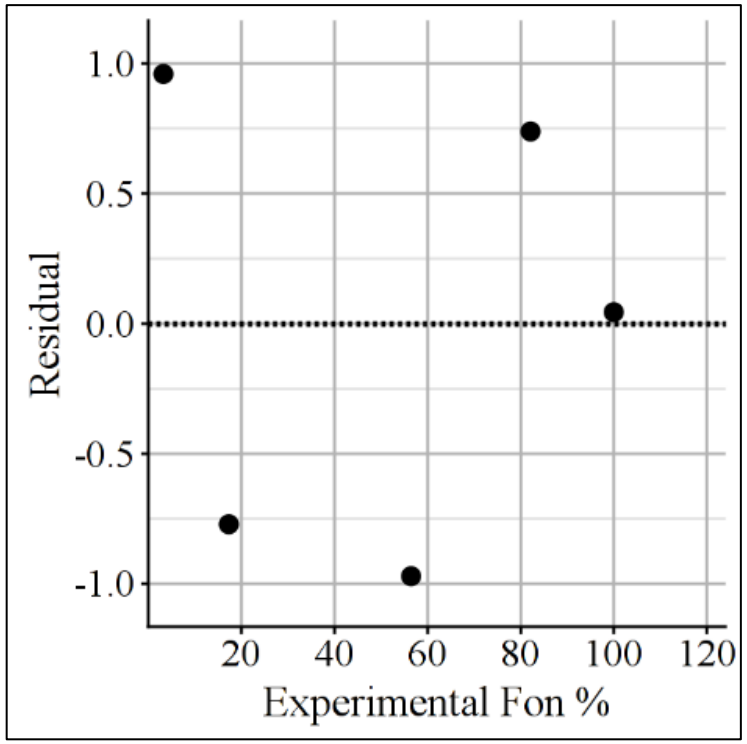


Figure created by Giovanni Piedimonte, 2014

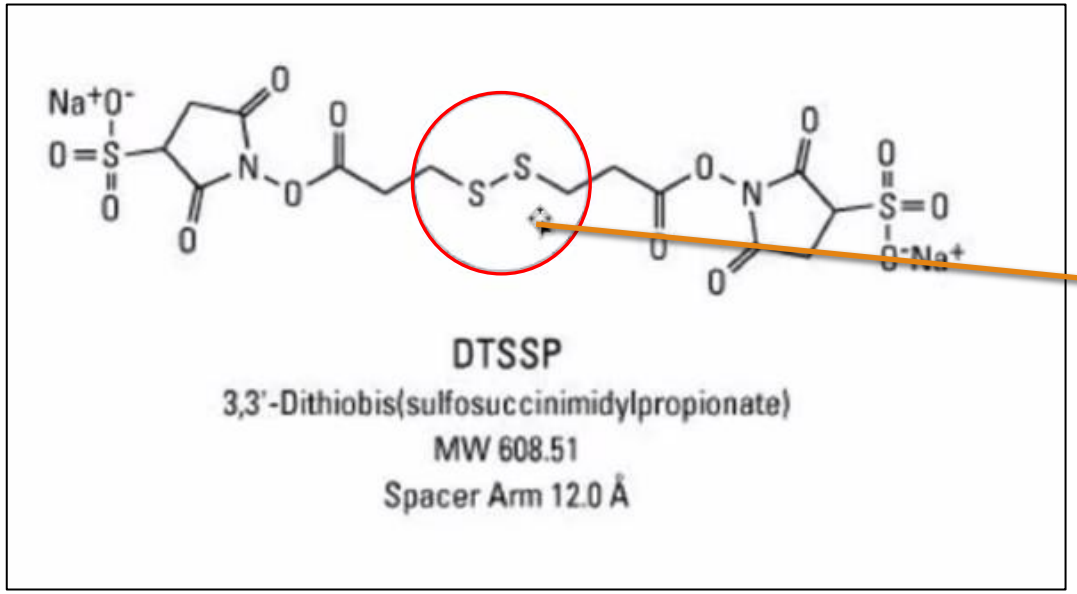
- Allow scientists to gain more information about spread of viruses
- Gives more information to healthcare providers to personalize treatments
- Faster and more accurate diagnostic results help limit spread and increase prevention



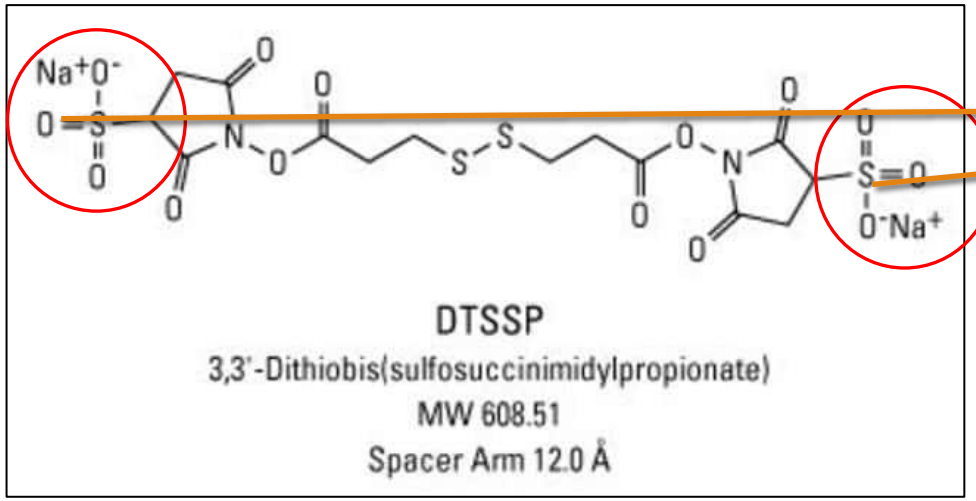


$$\lambda = -ln(1 - f_{on}) \qquad (1)$$

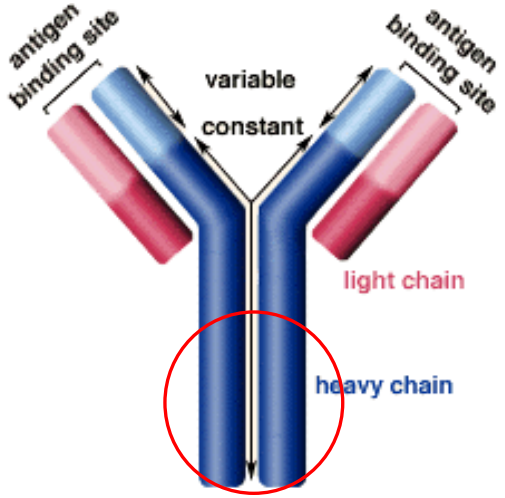
$$V = {}^{c}/_{\lambda} \qquad (2)$$



- Disulfide bonds get reduced into 2 **thiol** bonds
- Breaks the DTSSP into two parts
- Bonds to the gold ions using **thiol-gold** bonding



- **Sulfo-NHS-ester bonds** bind to the **amine bonds** to form **amide bonds**



- Binds to the **heavy chain** of antibody

Error Analysis

- Concentration of RSV abnormally high
- Laboratory mistakes
- MATLAB counting errors

Thank You

All diagrams were created by the researcher unless specified otherwise

All images were taken by the researcher unless specified otherwise