

Title: Single Photon Source on a Breadboard

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Abstract: <div id="Cleaner">In quantum information, one can prove that a secure quantum cryptography channel based on photon key distribution requires reliable single photon sources. If not, a potential eavesdropper may be able to get information using the extra photons. Current sources are based on either attenuated laser beams, which may produce randomly 2 or even more photons at a time following a poissonian statistics, or either based on two level-systems providing single photon sources often requiring cooling or complex set-ups.<div id="Cleaner">The goal of our experiment is to provide an easy, robust and compact single photon source using nonlinear optics (parametric down-conversion). We want to study its statistics and compare it to other photon sources. We could use this heralded single photon source to create a quantum communication channel.

Single Photon Source on a breadboard

Erwann Bocquillon

4th Canadian Quantum Information Students' Conference

June 2007

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Single photon source on a breadboard

Motivations

- Need single photons (for quantum cryptography)
- Educational project :
 - 1 student
 - a prototype to be sold

Constraints

- As cheap as possible
- As small as possible : breadboard
- Easy and robust source

Plan

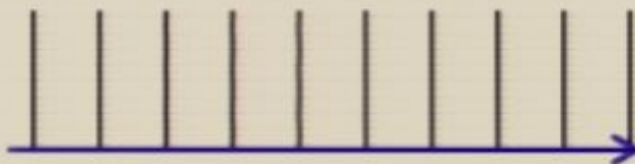
- A single photon source ?
 - What is an SPS ?
 - Different types of SPS
 - How to characterize an SPS ?

- Basic principles of the experiment
 - Parametric down-conversion
 - How to make an SPS ?

- Results & next steps
 - Second harmonic generation
 - Next steps

I - A single photon source ?

- What is an SPS ?
 - 1 photon at a time
 - deadtime after each photon
 - recording arrival times :



- natural realization : 2-level systems

□ Different types of SPS

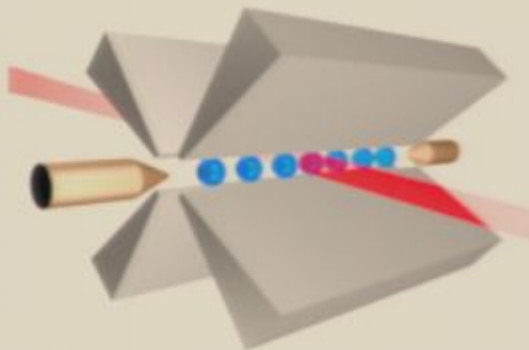
■ Single dipole, quantized level systems



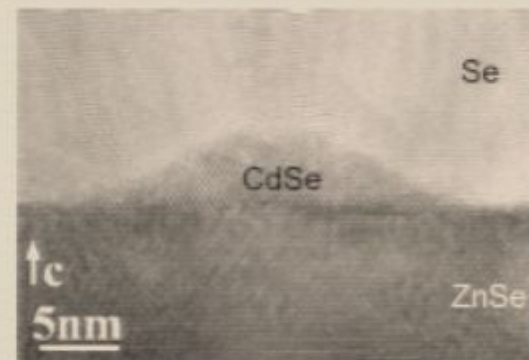
takes time to “reload” → 1 photon

■ examples :

- trapped atoms or ions with optical transition between two levels
- quantum dots
- nanocrystals
- colored centers



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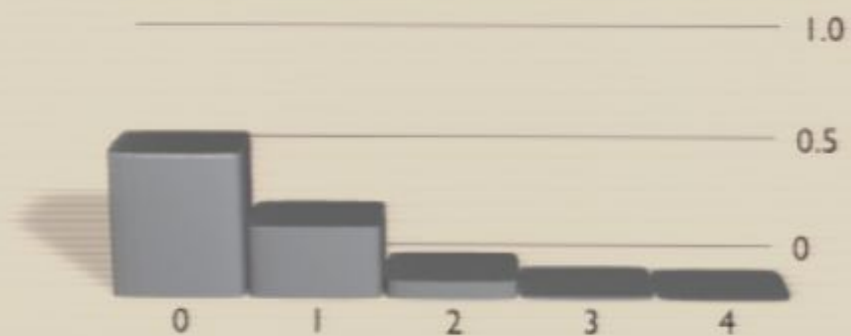


NPSC
Université J. Fourier, Grenoble

- Attenuated laser : Poissonian distribution of the photons

$$P_1, P_2 = \frac{P_1^2}{2} \dots$$

$$P_n \propto P_1^n$$



Photon number distribution, $\langle n \rangle = 0.5$

- Other approximated SPS
 - Parametric down conversion
- Non single photon source
 - "chaotic" classical light :
 - incandescence lightbulb
 - neon
 - spectral lamp

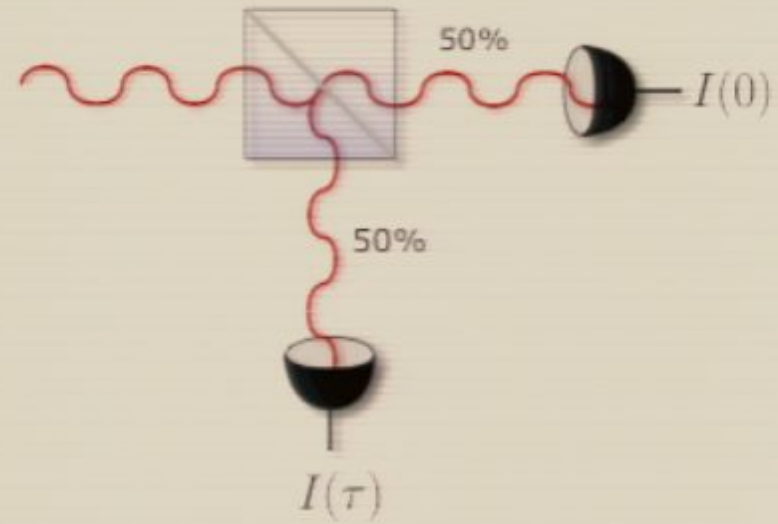
□ How to characterize them?

1 detector : not enough!

■ The second order coherence function $g^{(2)}(\tau)$

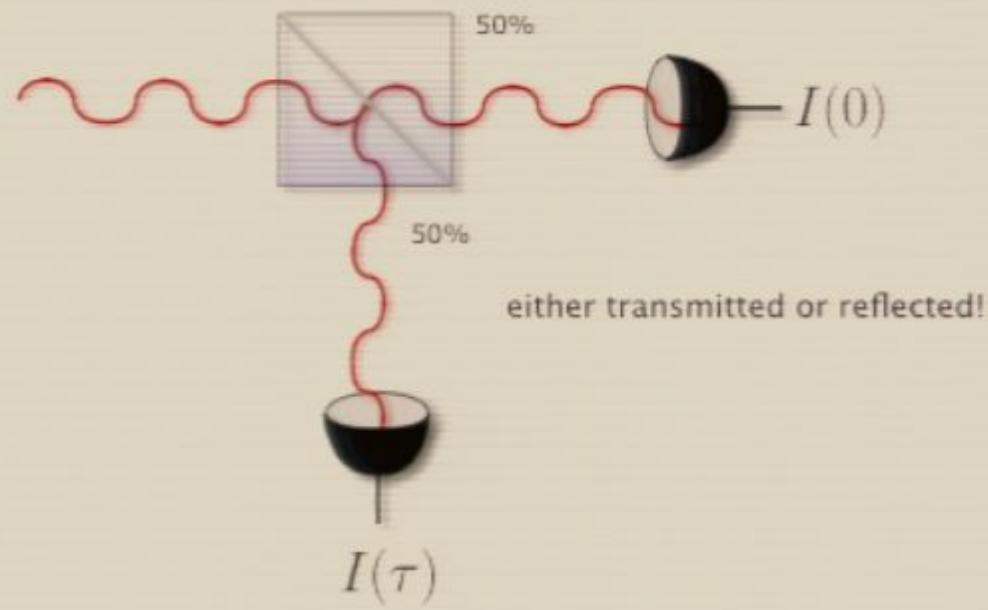
- Measures the correlation of the intensity of the field
- The intensity is related to the number of photons

$$g^{(2)}(\tau) = \frac{\langle \hat{I}(0)\hat{I}(\tau) \rangle}{\langle \hat{I}(0) \rangle \langle \hat{I}(\tau) \rangle}$$



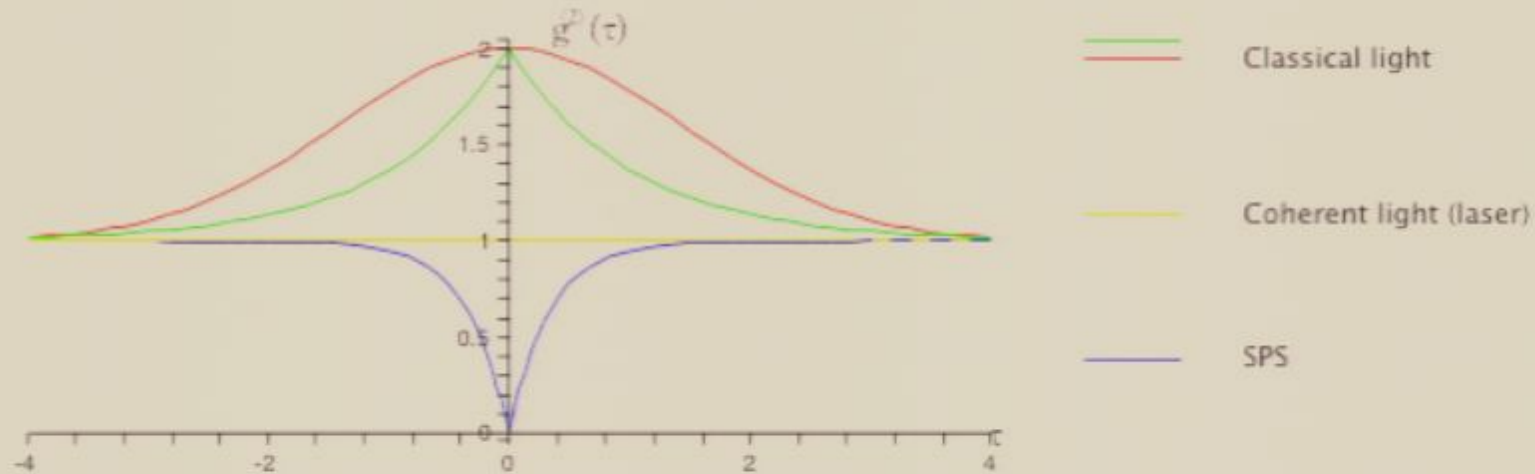
■ Measuring the $g^{(2)}$ function

- record first photon, $t=0$
- record second photon, $t= \tau$
- iterate
- statistics on τ
- histogram



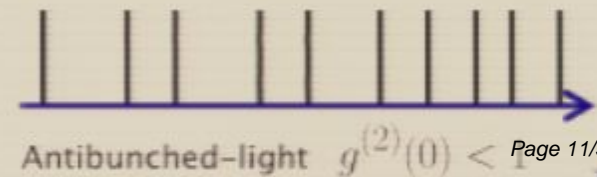
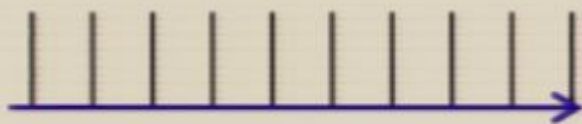
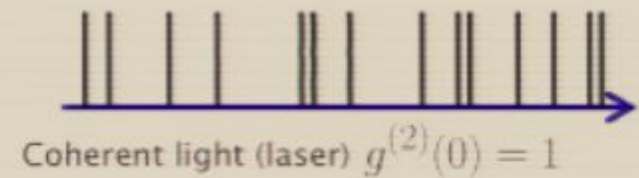
■ Photon bunching and anti-bunching

- Each type of light has a different $g^{(2)}$



Coherence functions for different types of light

- Recording arrival times of the photons :



II - Experimental setup

□ Parametric down-conversion

■ Non-linear effect

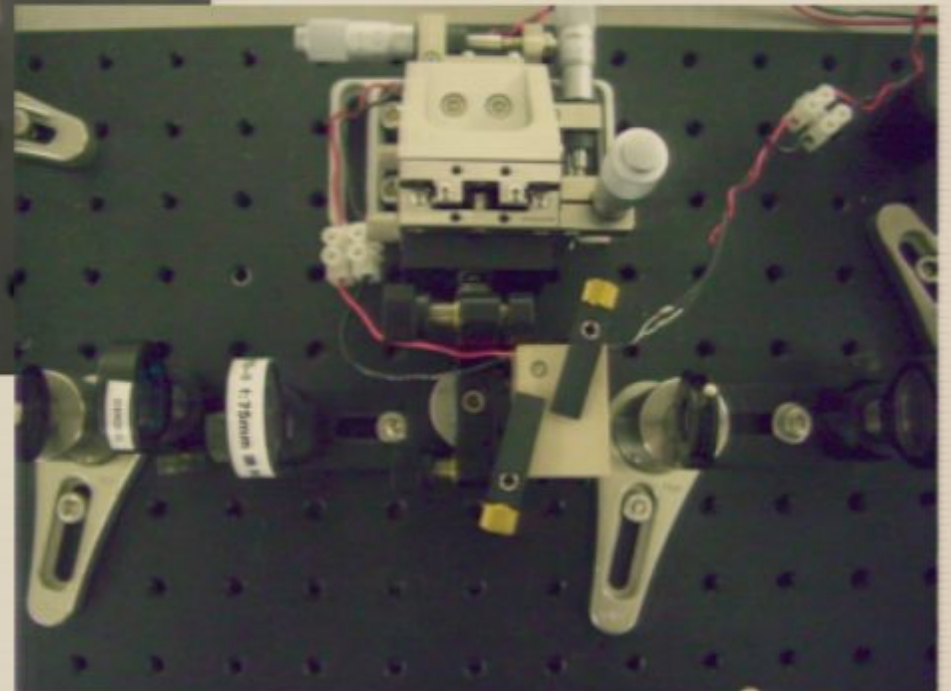
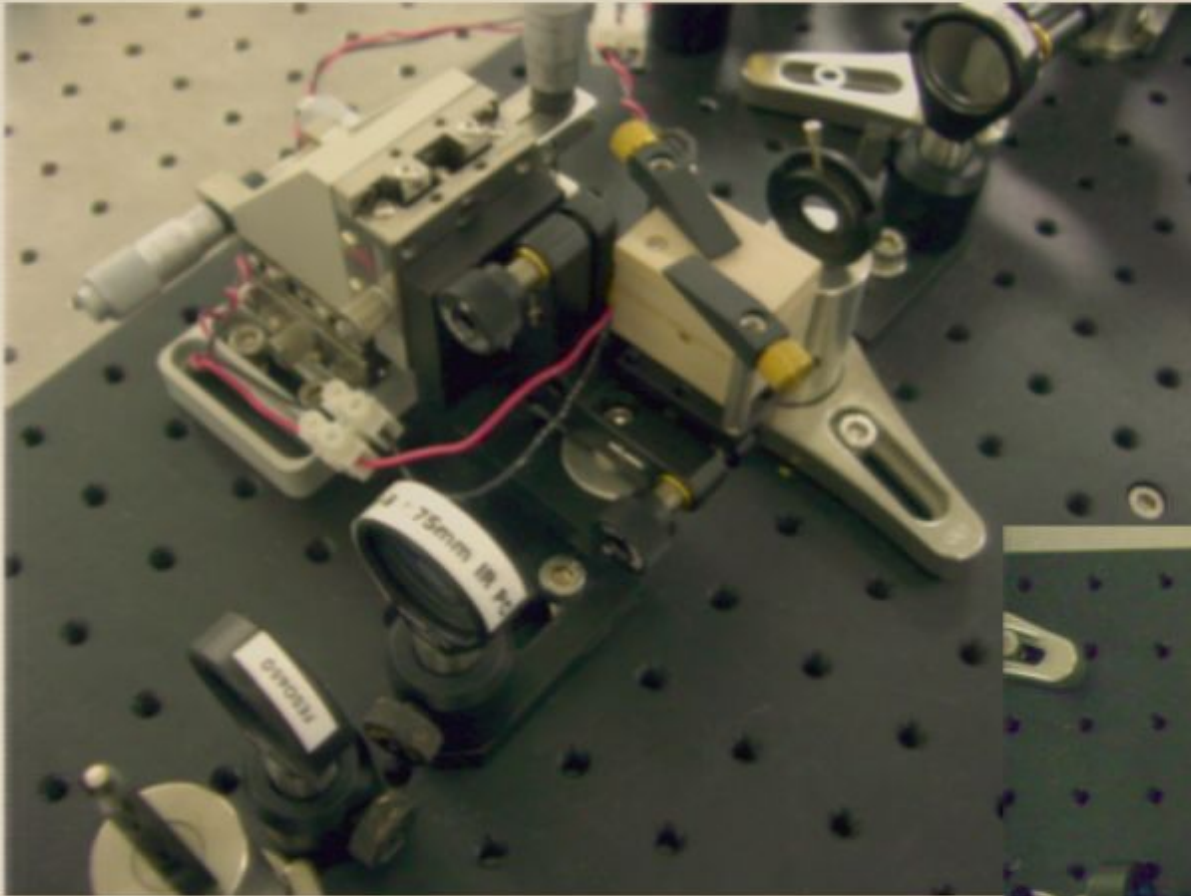
- non-linear medium → generating frequencies
- 1 blue photon (405 nm) → 2 (infra)red photons (810 nm)



- conservation equations :

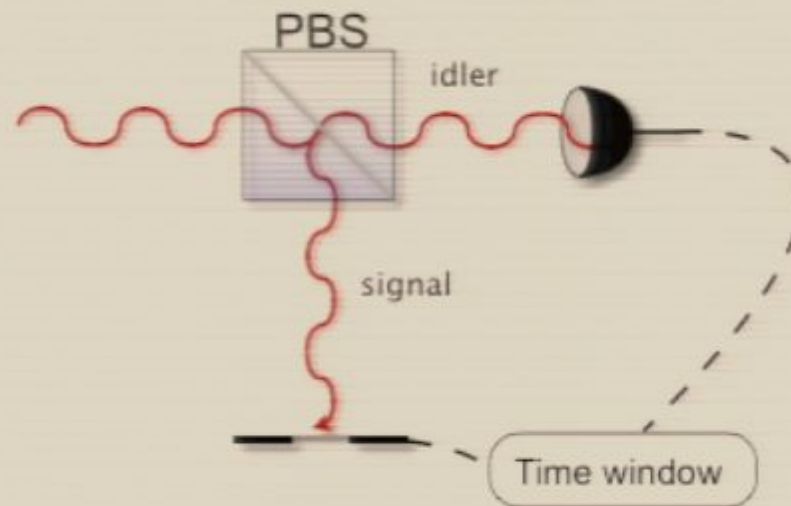
$$\begin{aligned}\omega_p &= \omega_i + \omega_s \\ \vec{k}_p &= \vec{k}_i + \vec{k}_s\end{aligned}$$

■ Setup



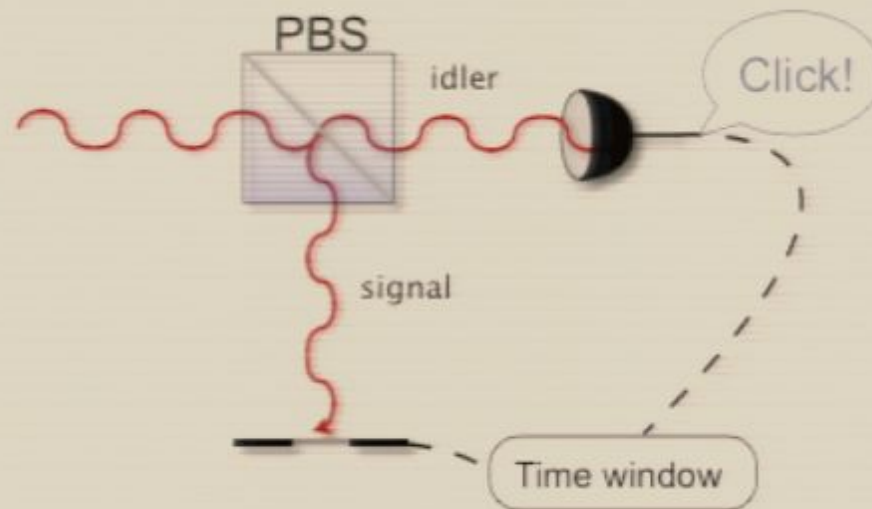
□ How to make an SPS ?

- Photons are created by pairs ! → separate the two beams
→ using polarization
- Use the “idler photon” to herald the “signal photon”



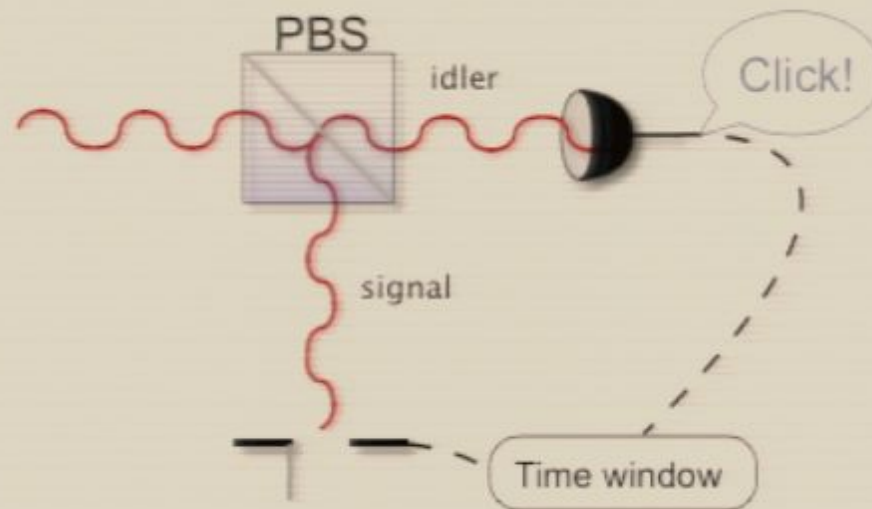
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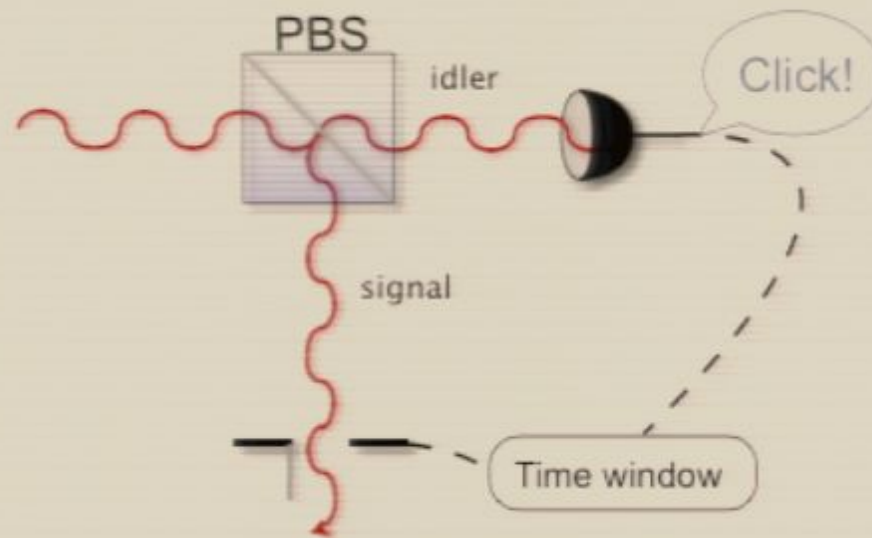
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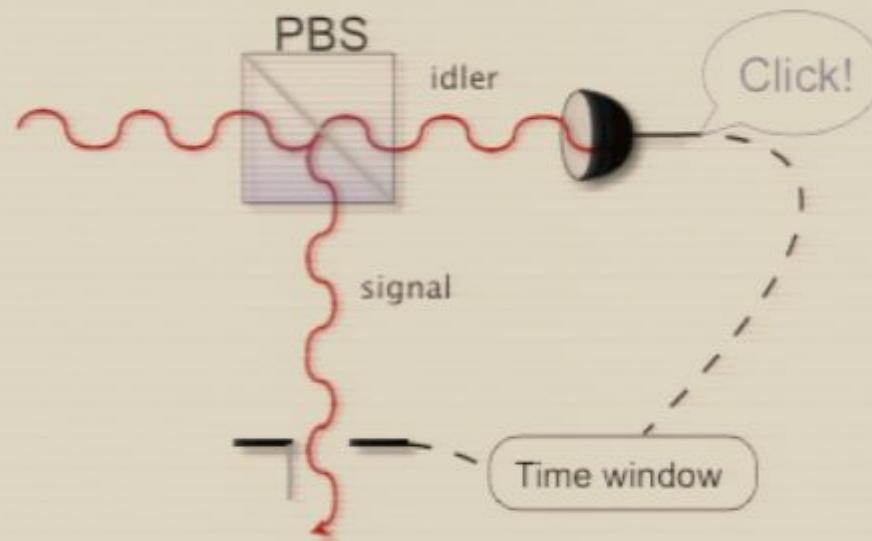
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Heralded single photon !

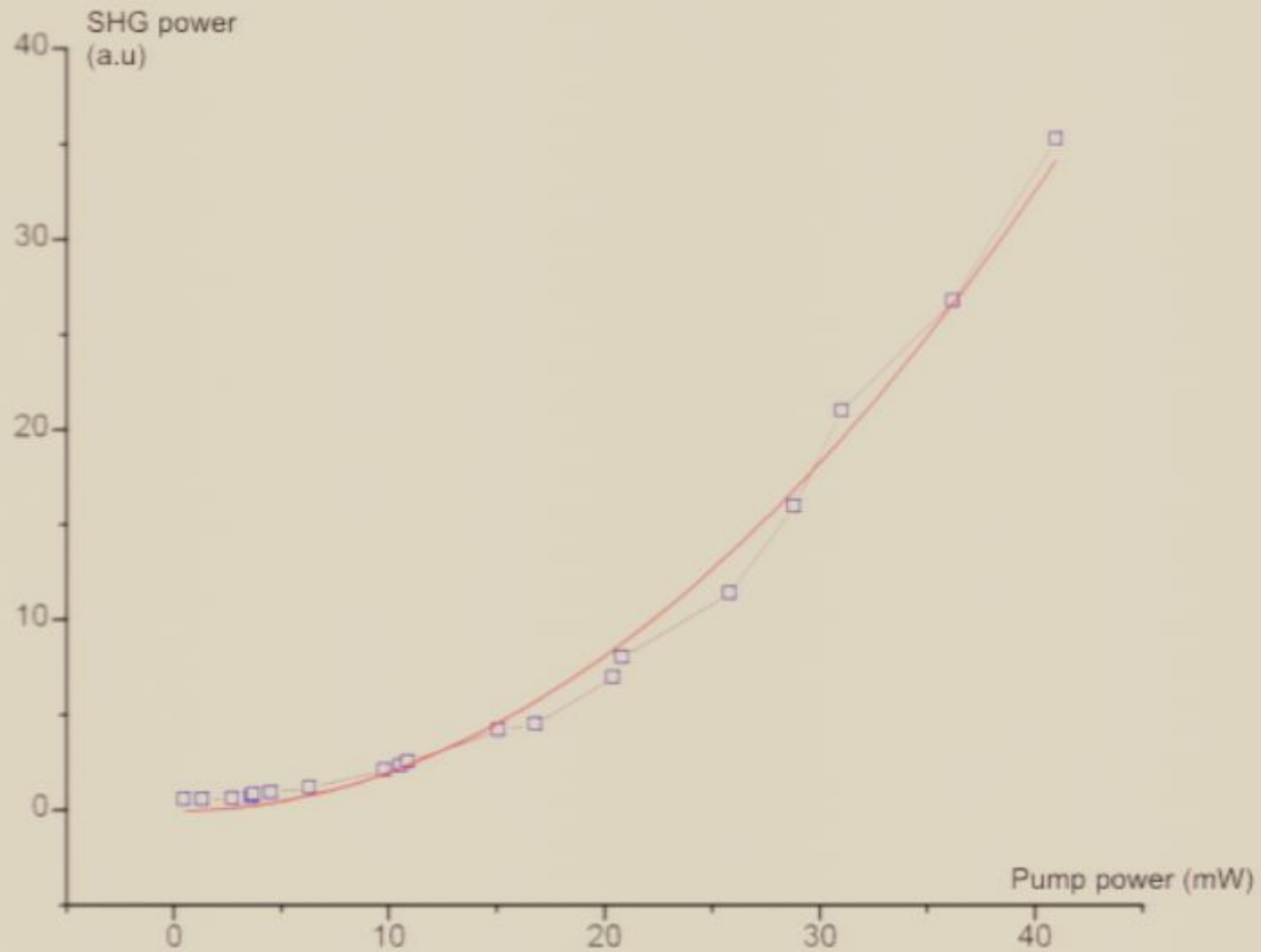
III - Results and next steps

- A (few) results...on Second Harmonic generation

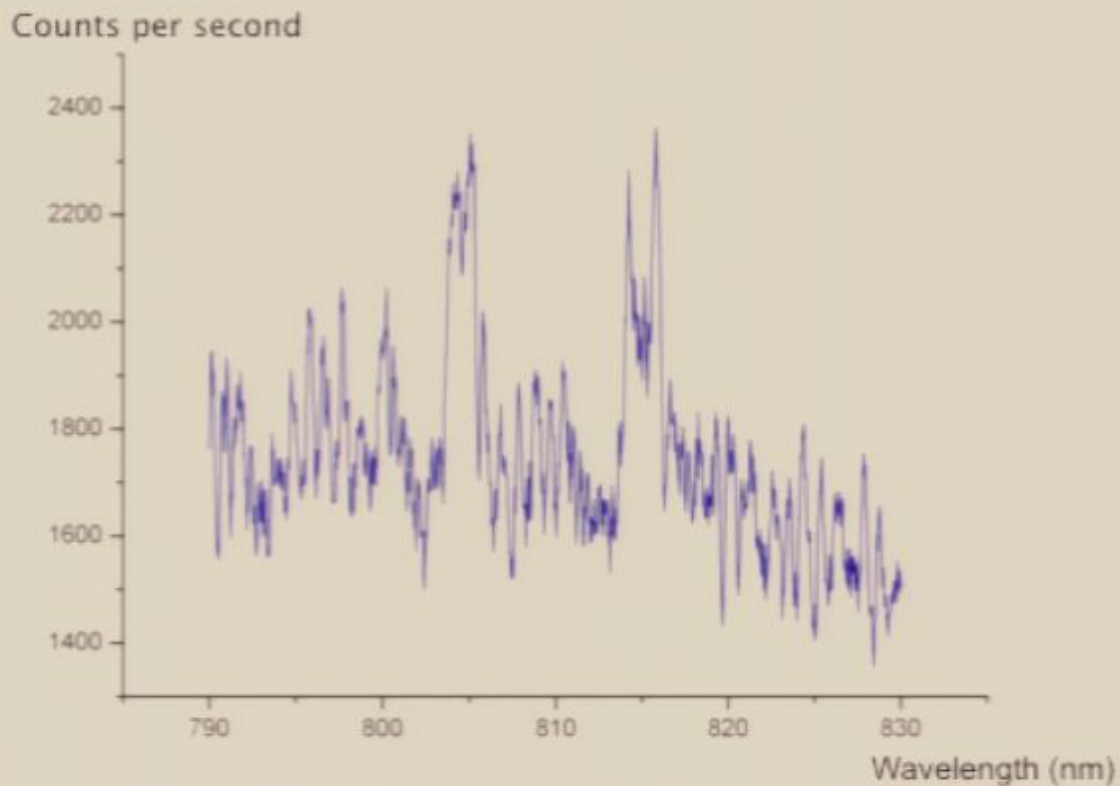


- inverse process
- efficiency : $\eta_{SHG} = 0.03\% \rightarrow \eta_{PDC} \sim 10^{-6}\%$
- optimal temperature and wavelength

■ non-linearity : $\mathcal{P}_{SHG} \propto \mathcal{P}_{pump}^2$

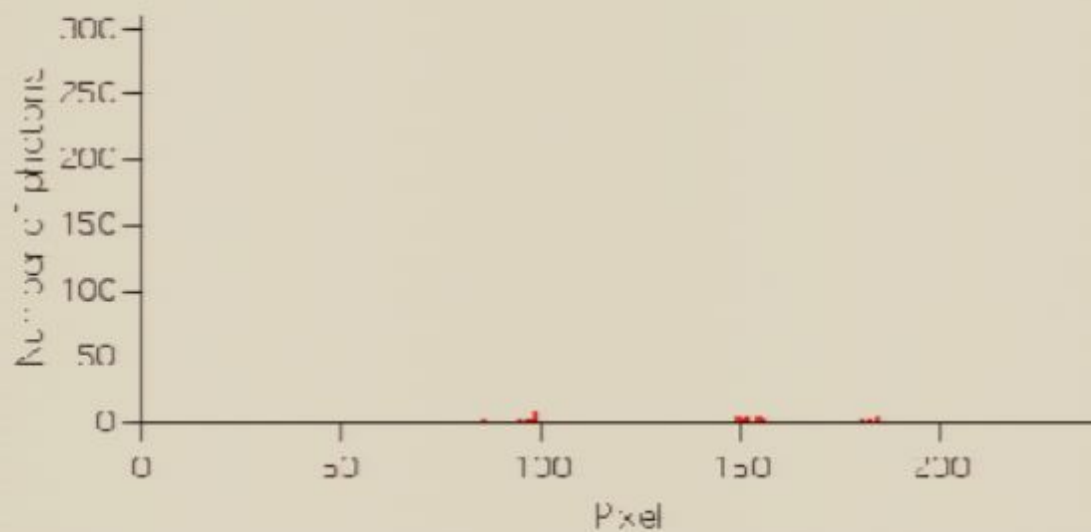
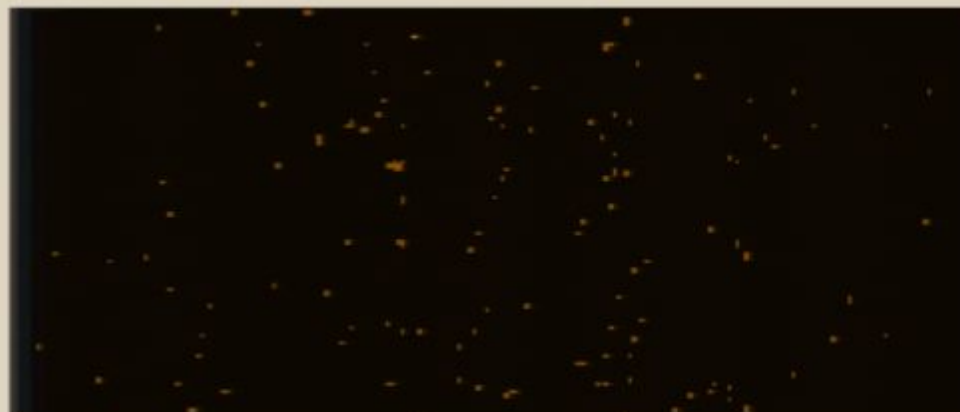


- Next step
 - Find the red photons

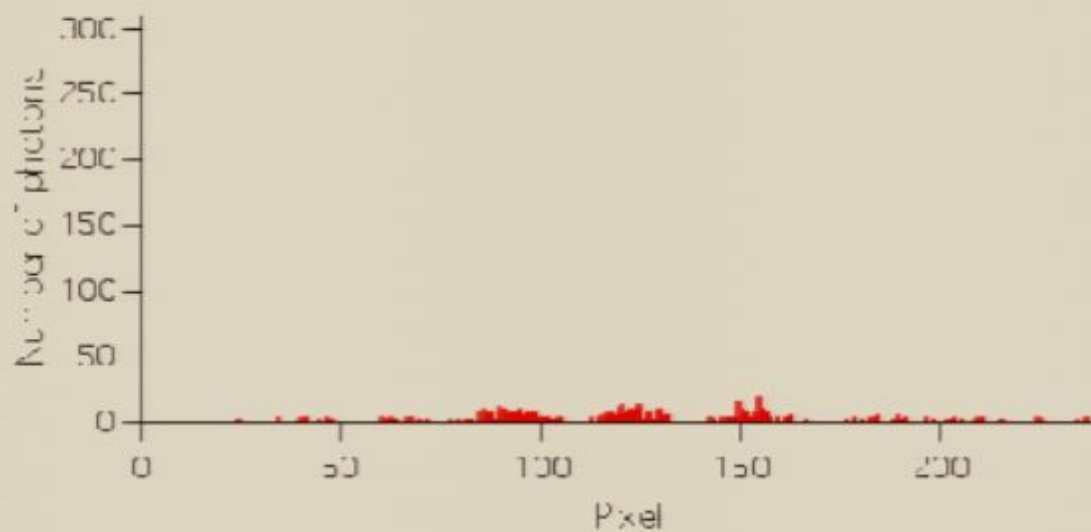
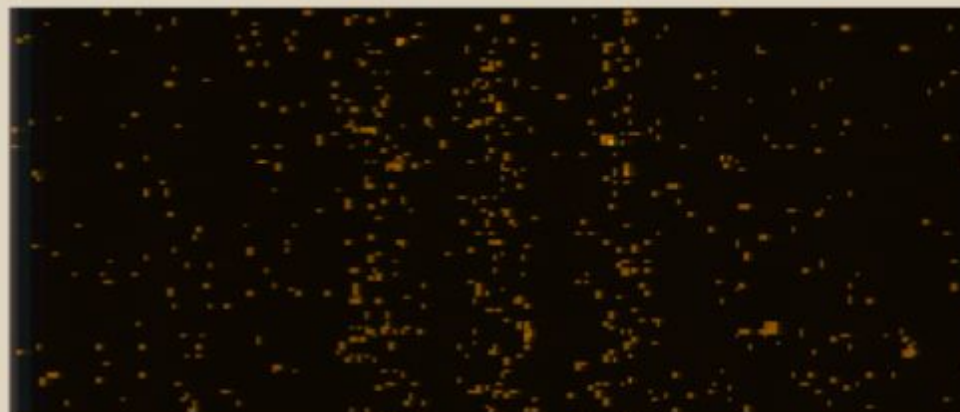


- Plot the $g^{(2)}$ function
- Study the statistics of the source

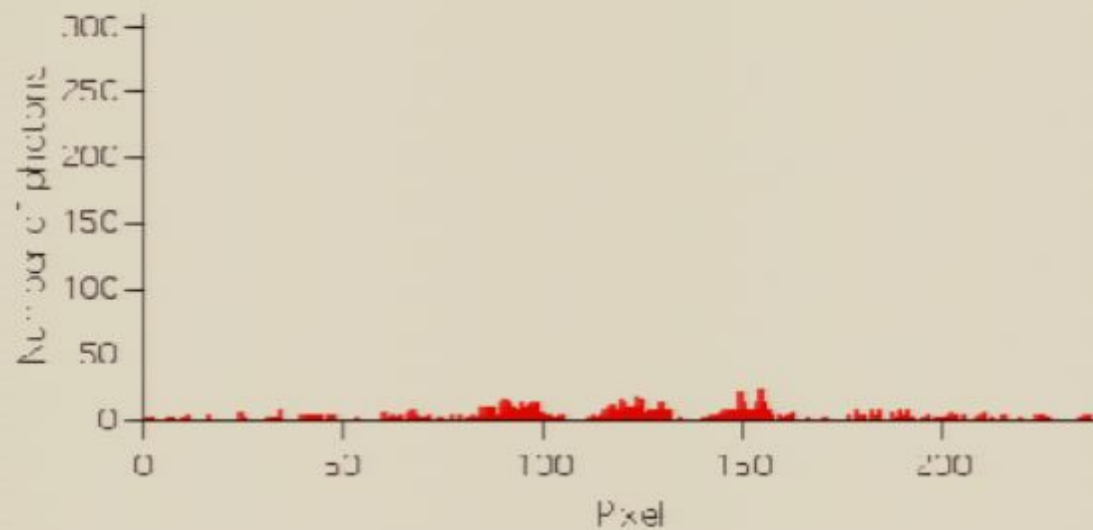
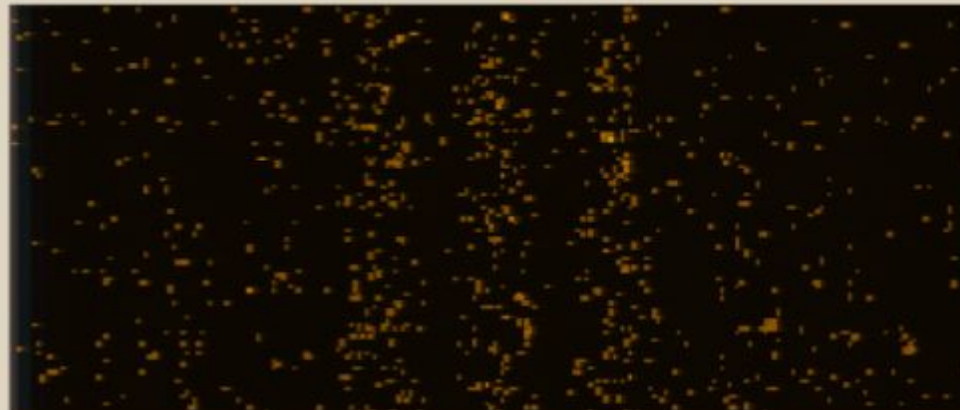
- Future directions : double slit experiment



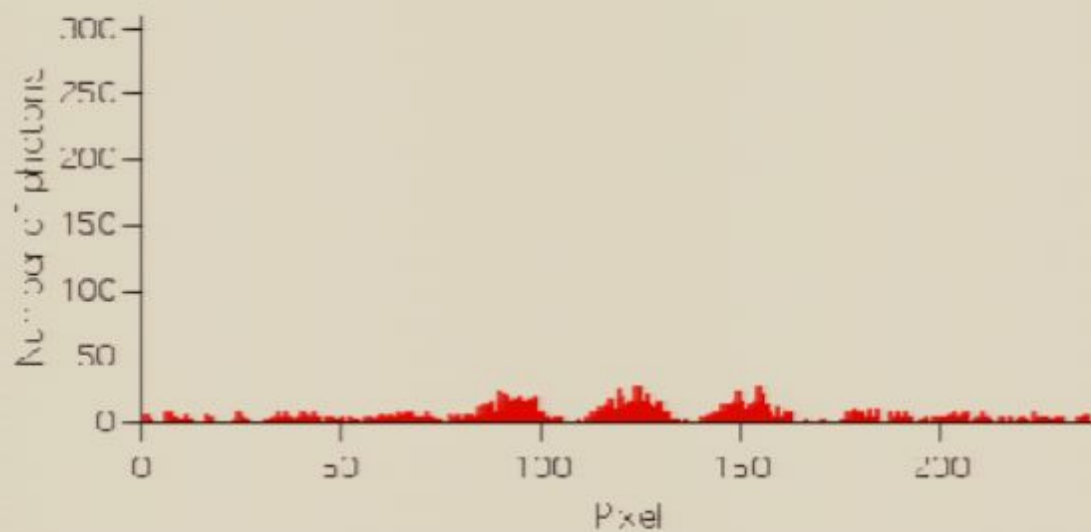
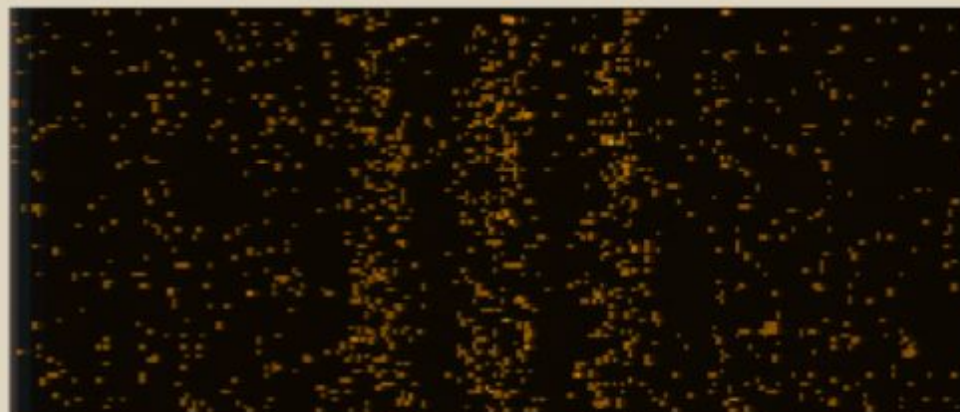
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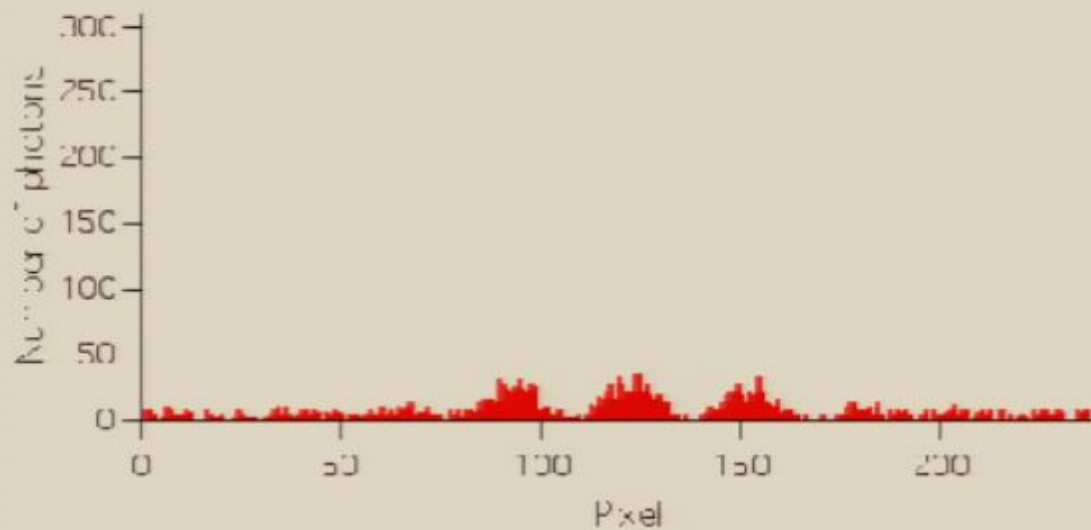
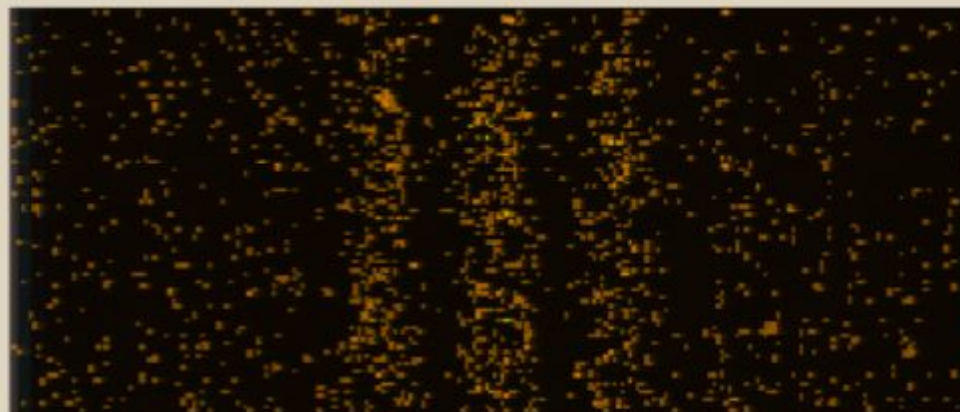
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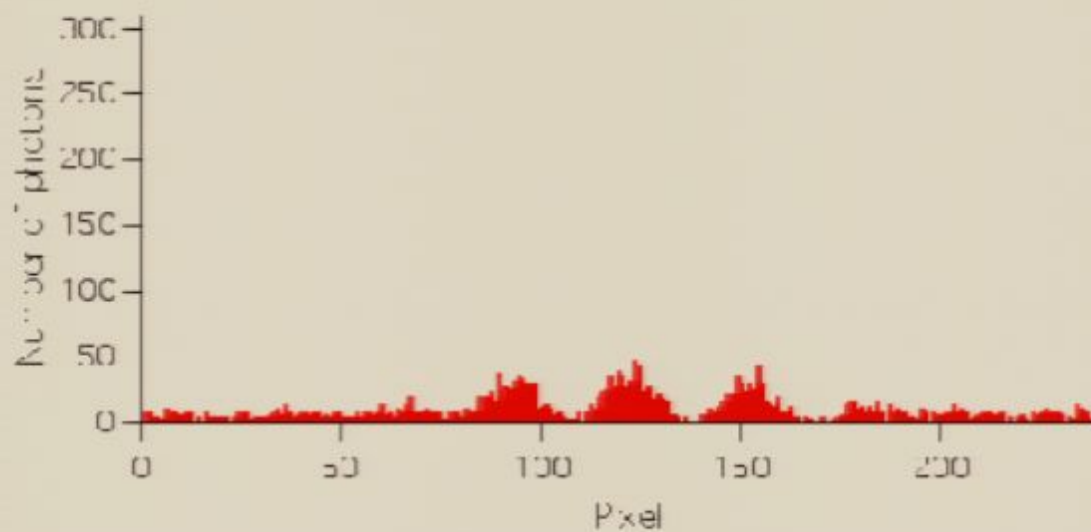
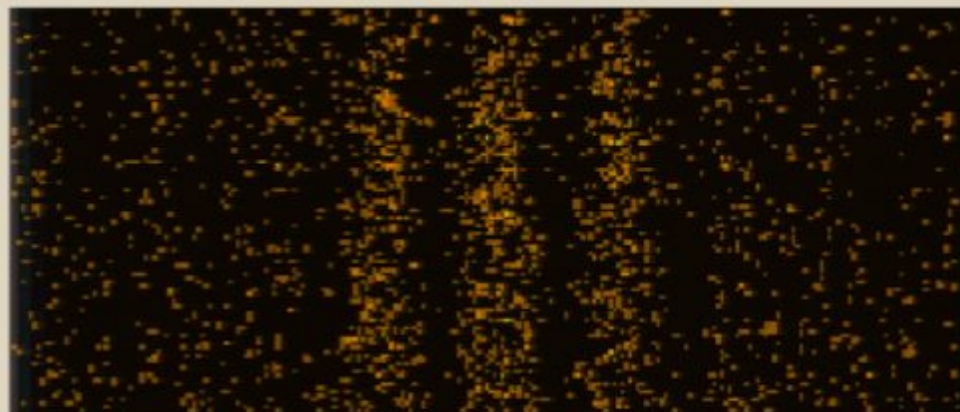
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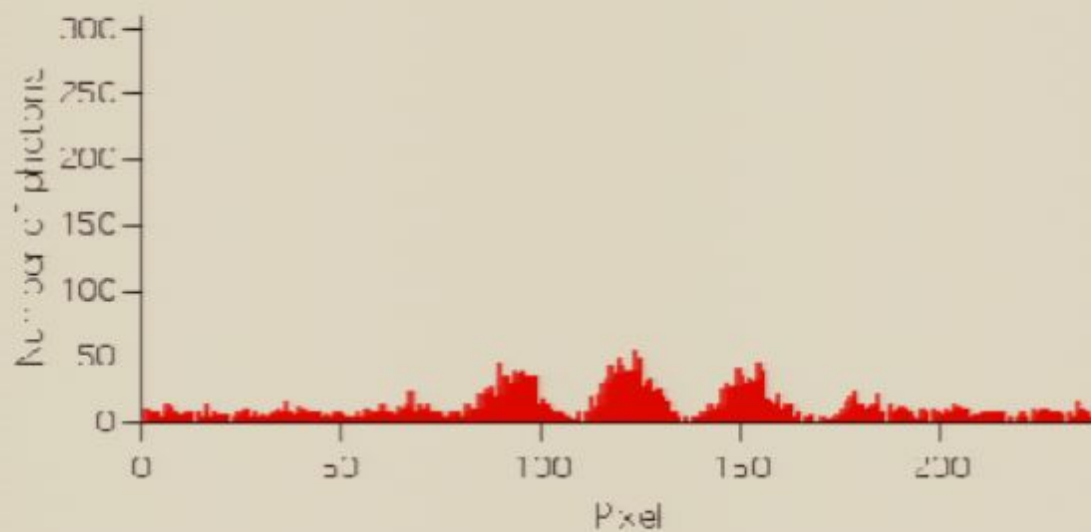
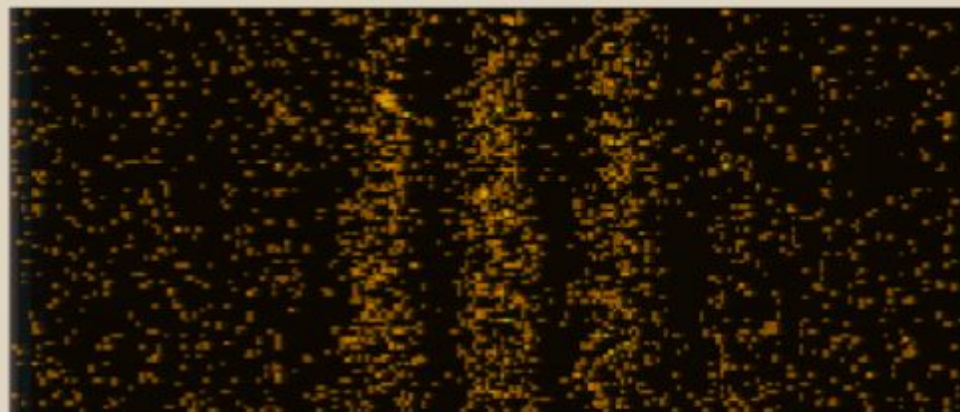
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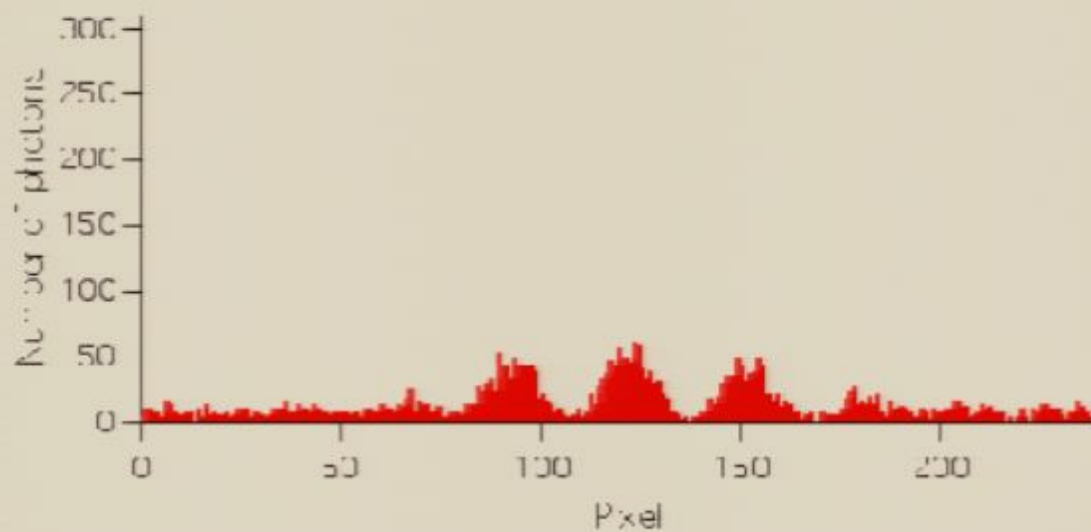
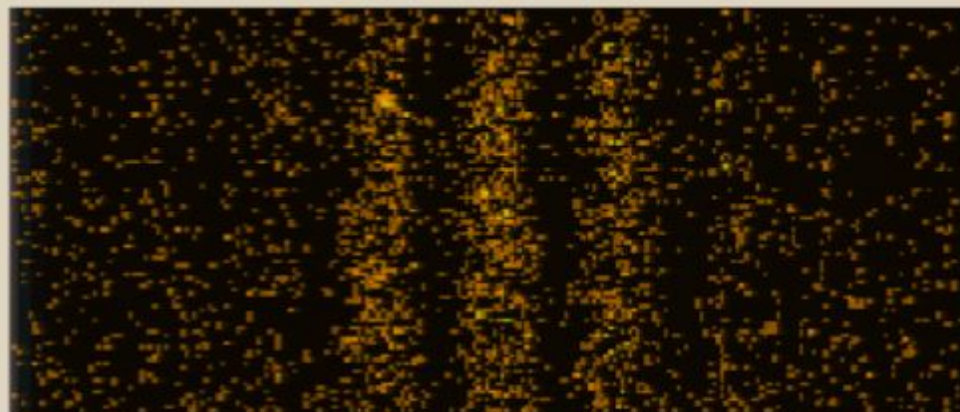
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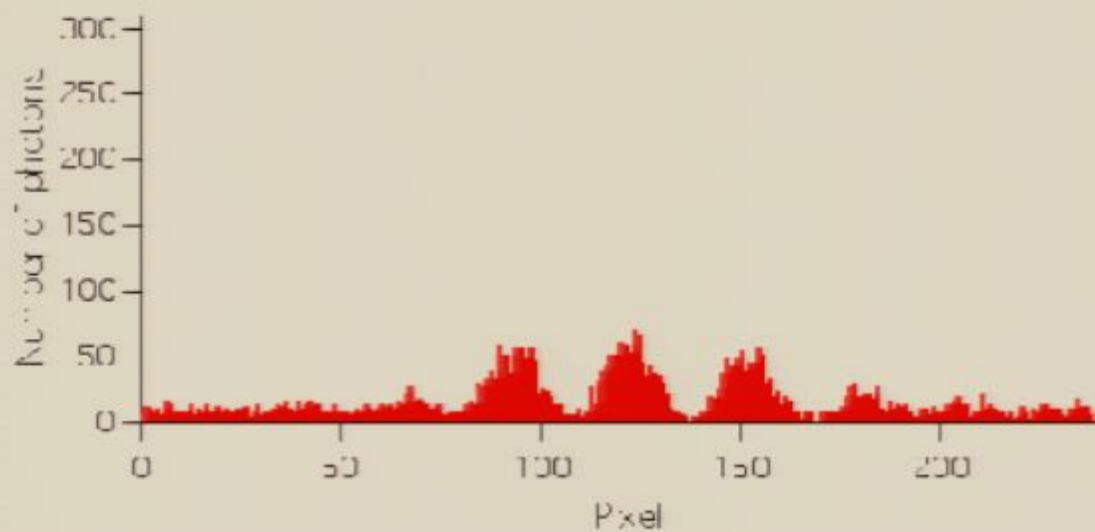
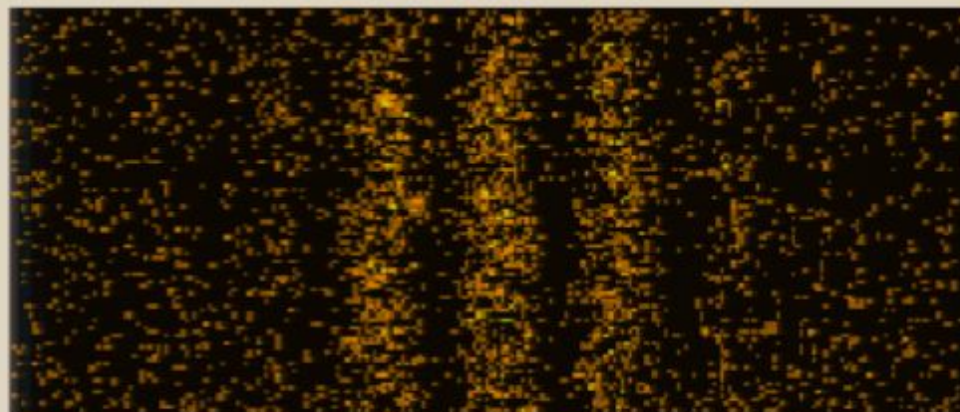
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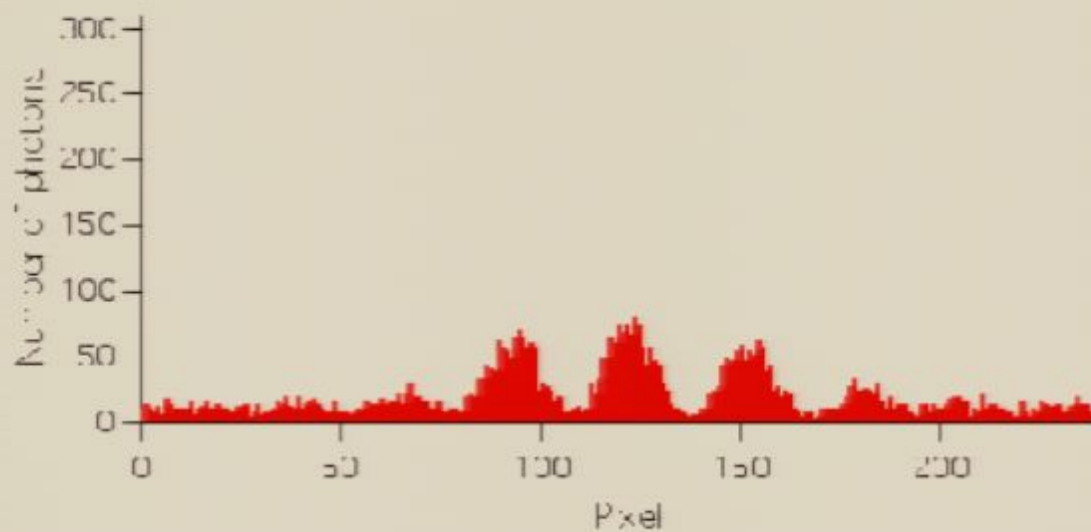
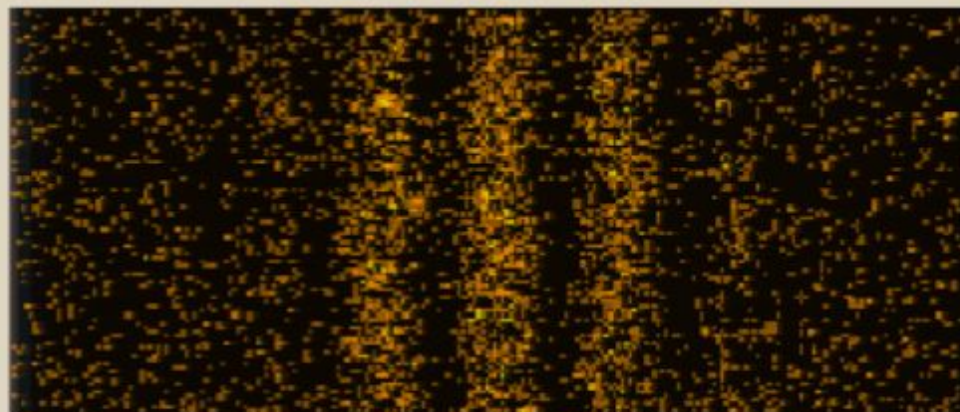
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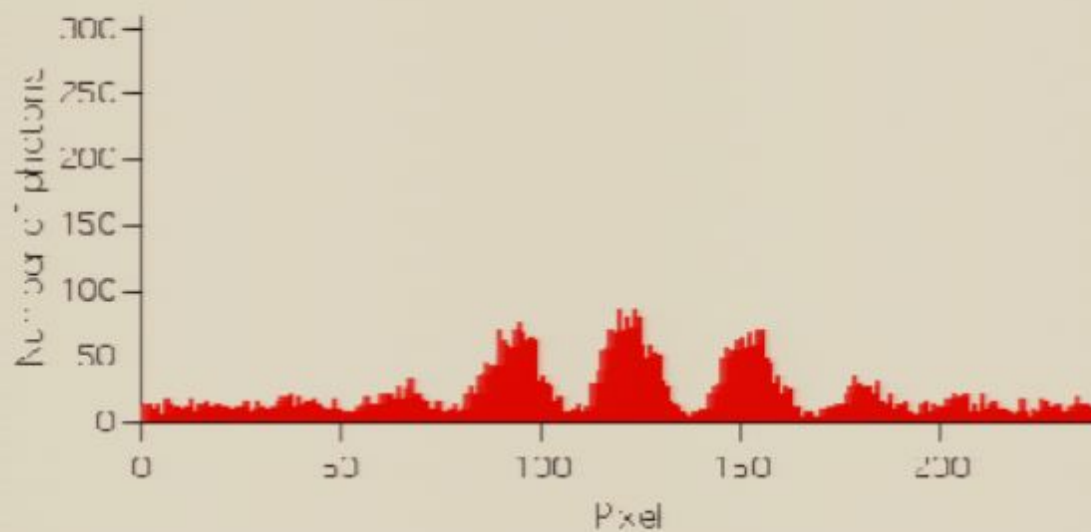
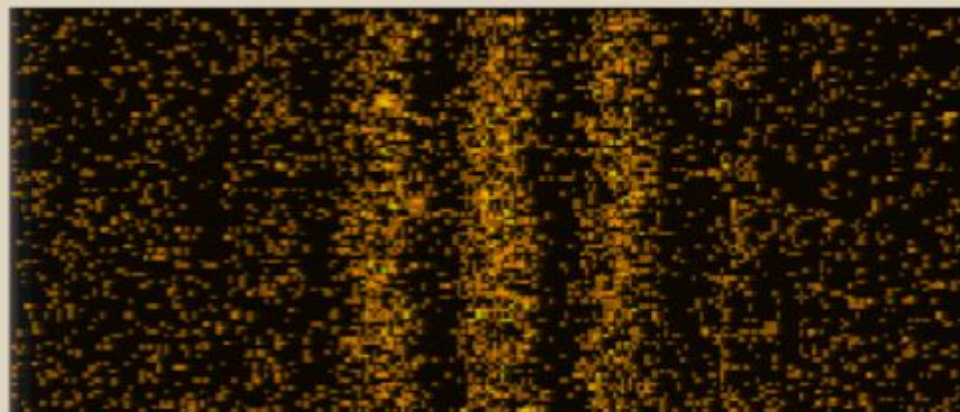
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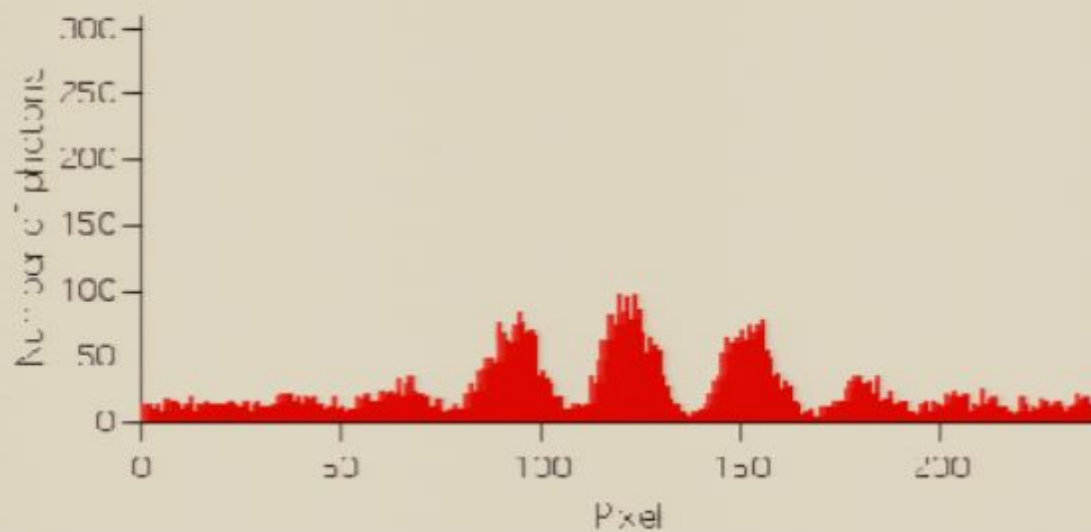
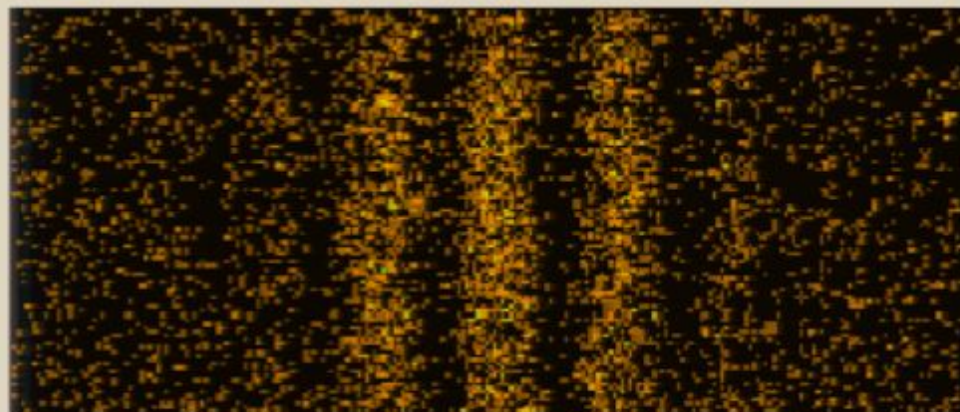
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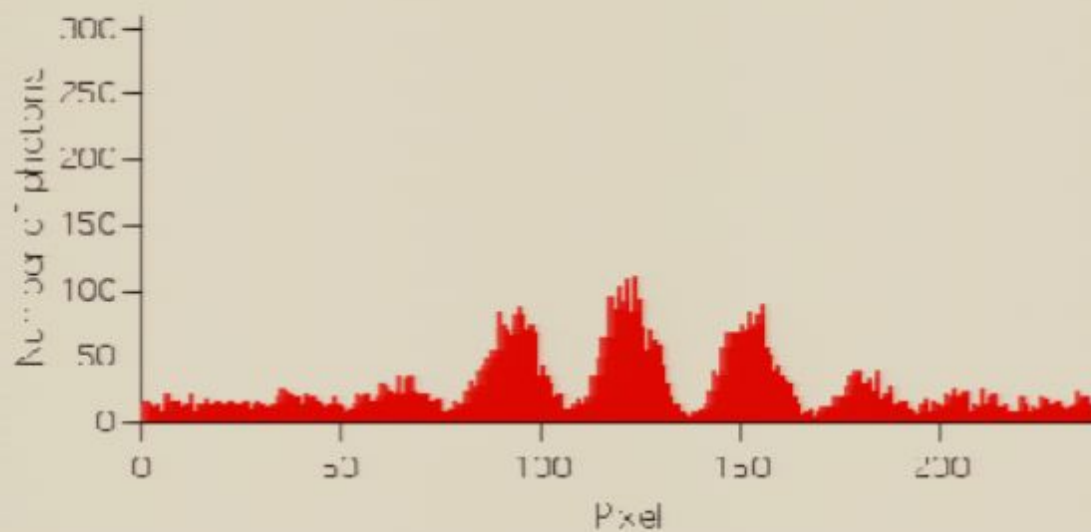
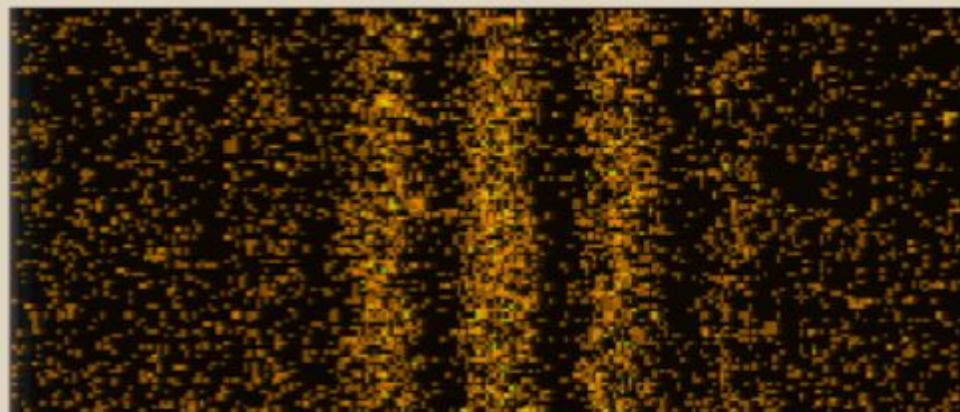
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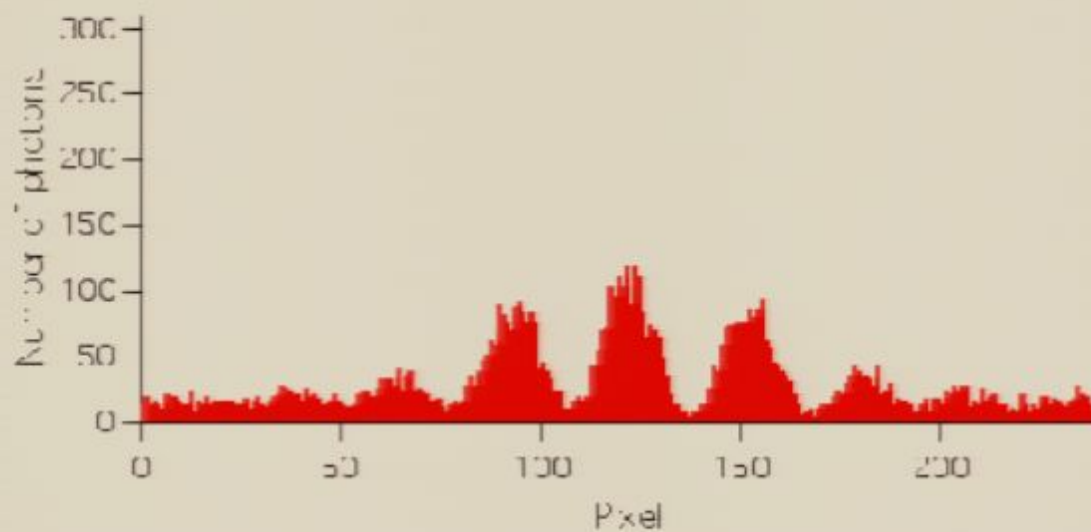
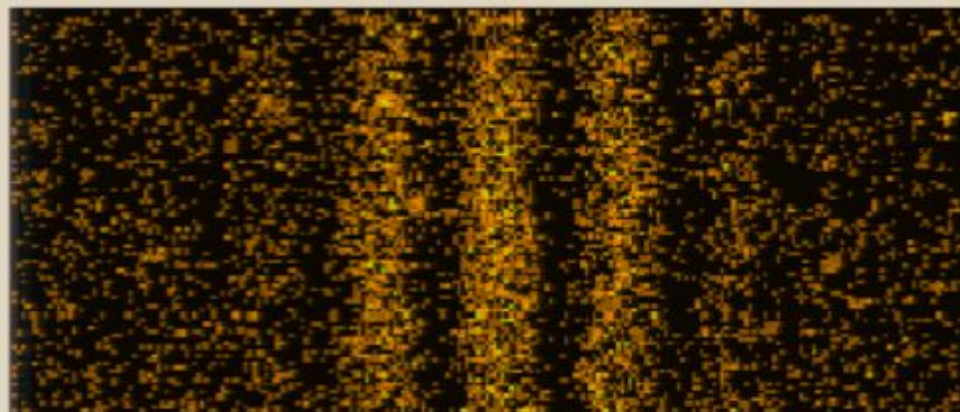
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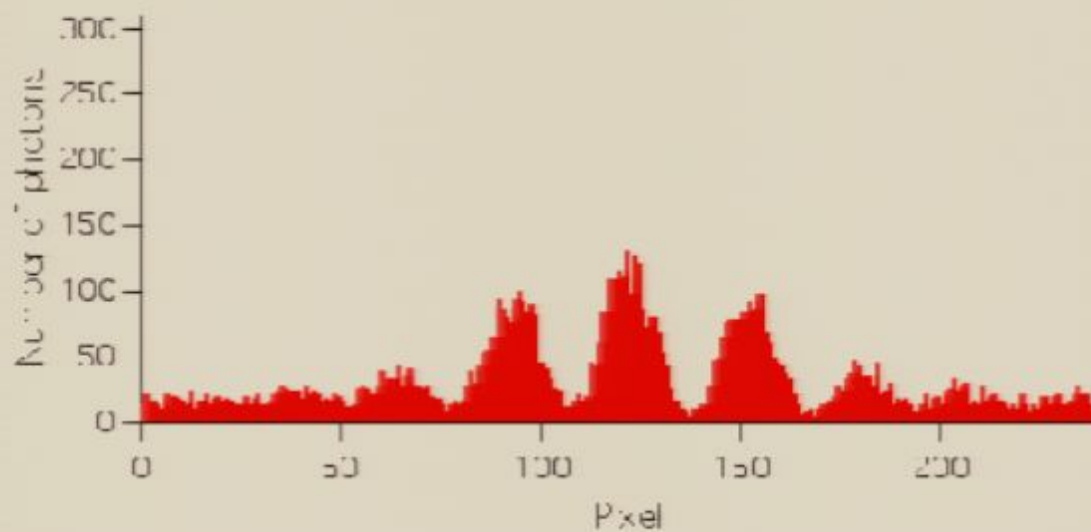
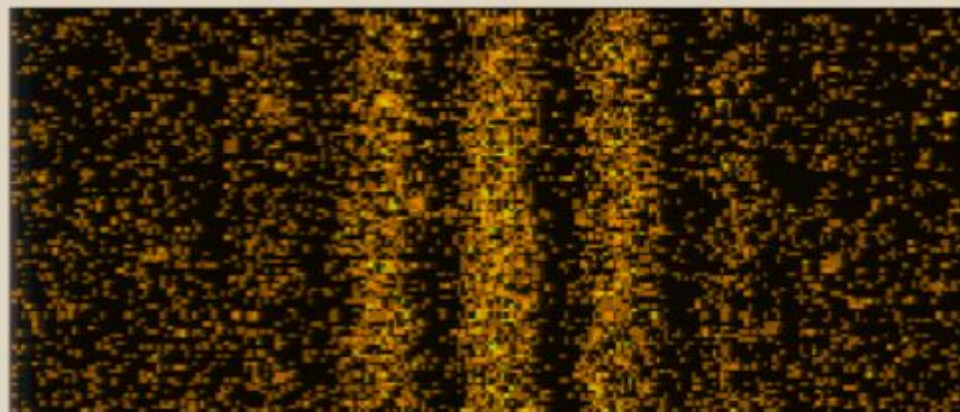
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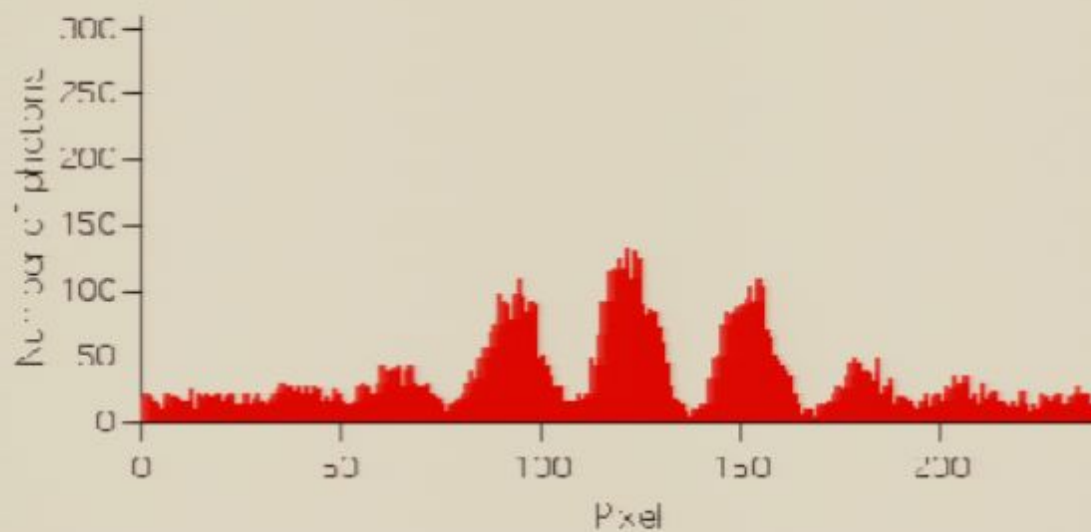
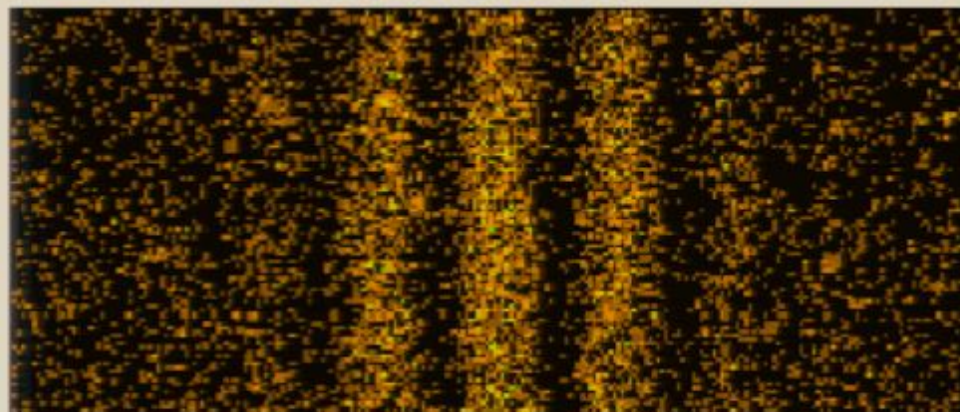
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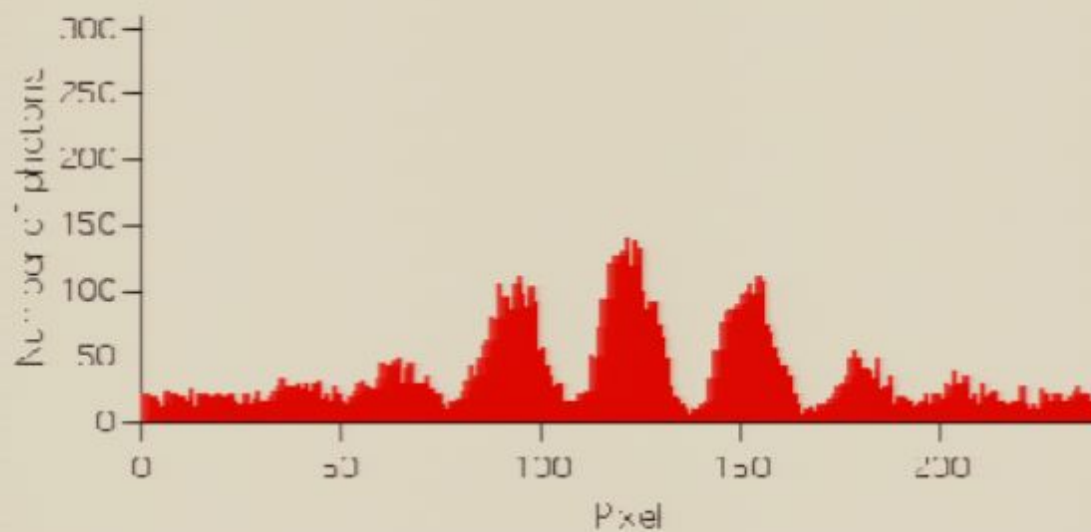
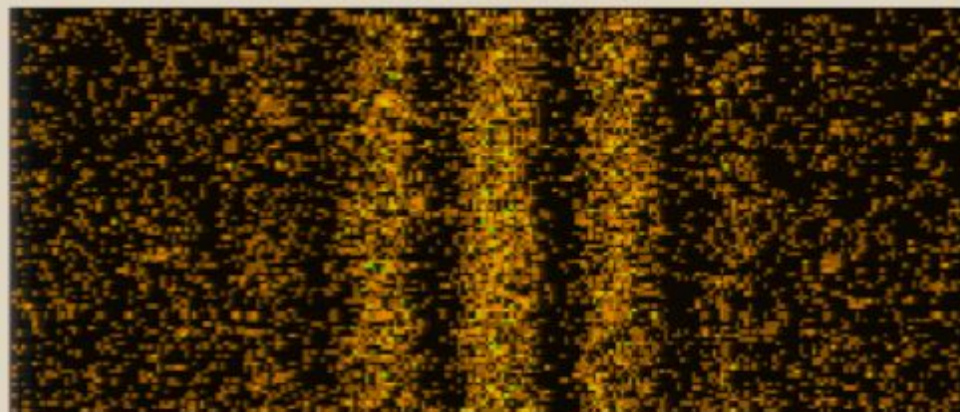
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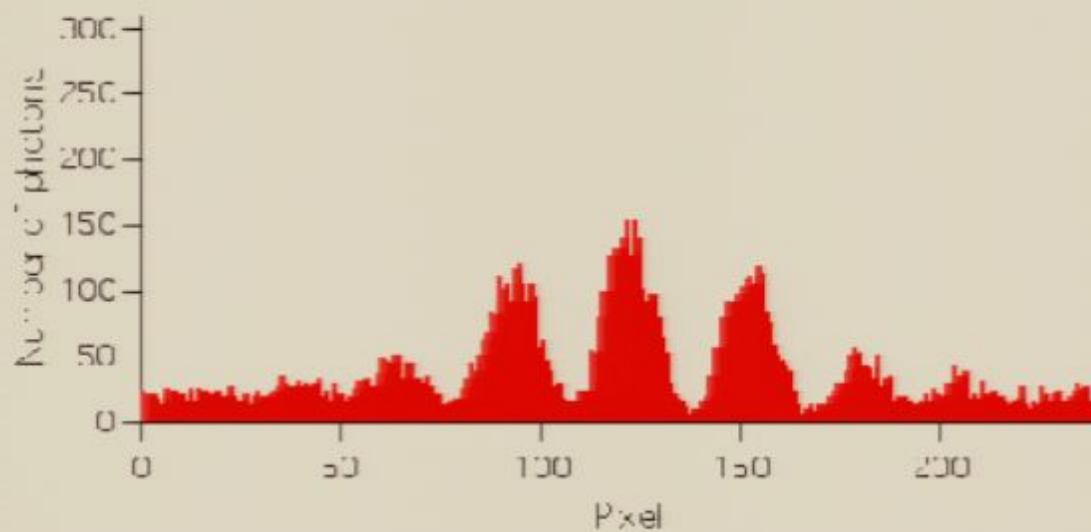
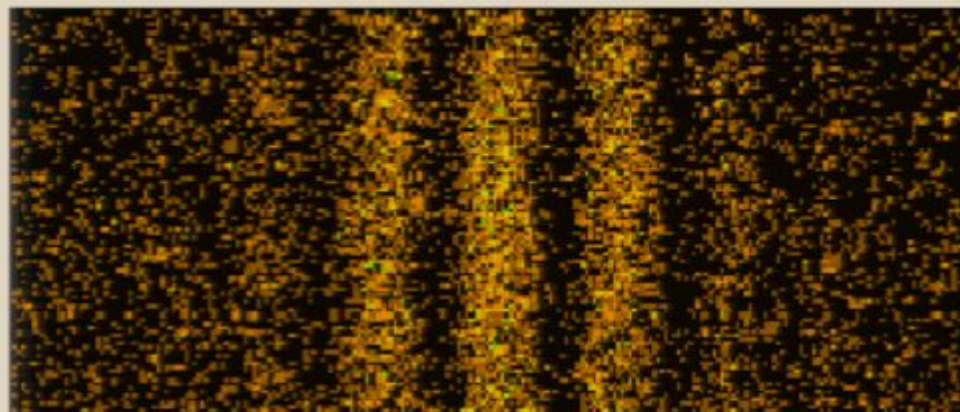
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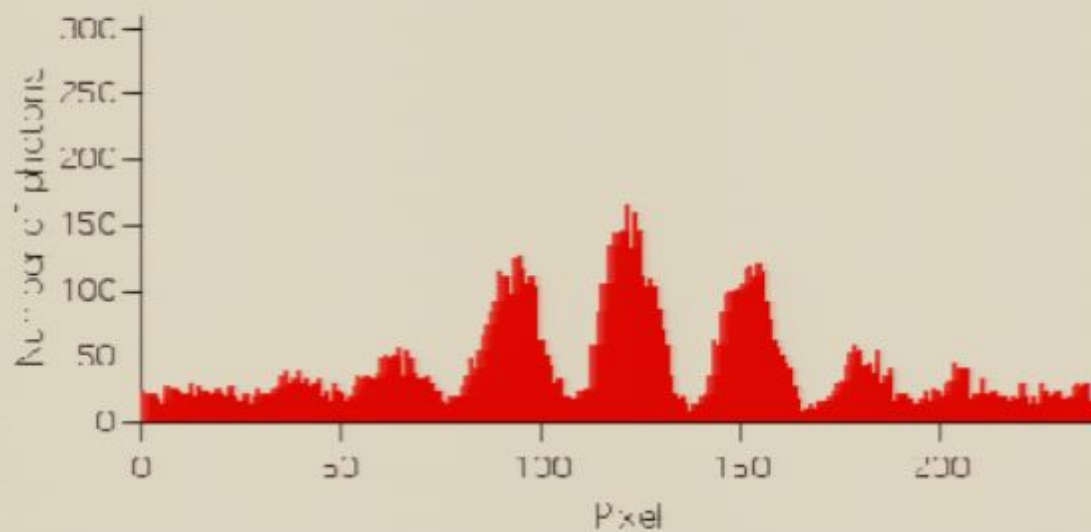
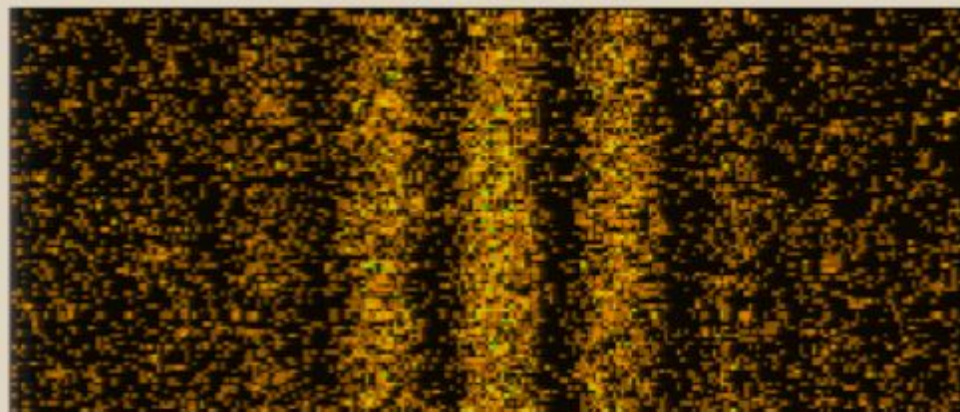
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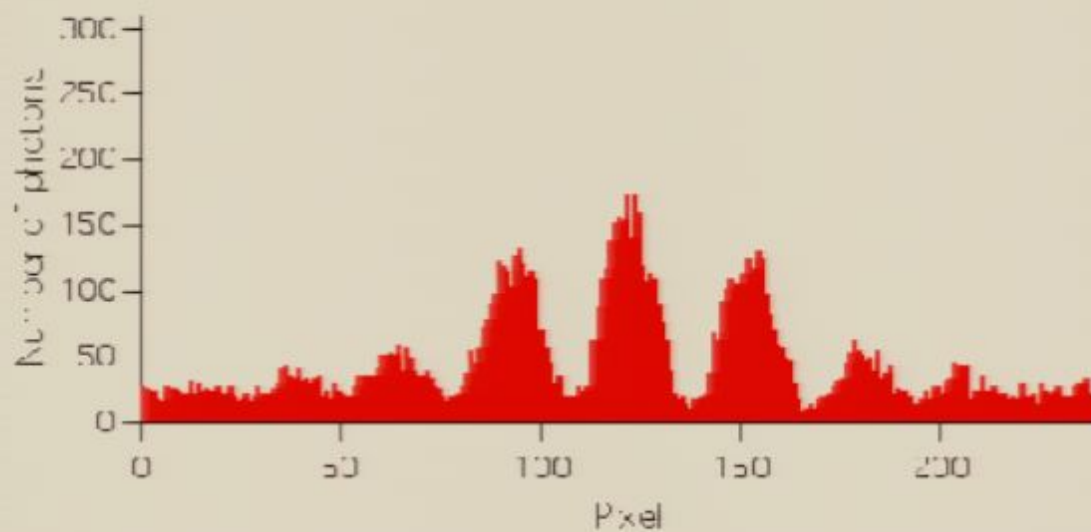
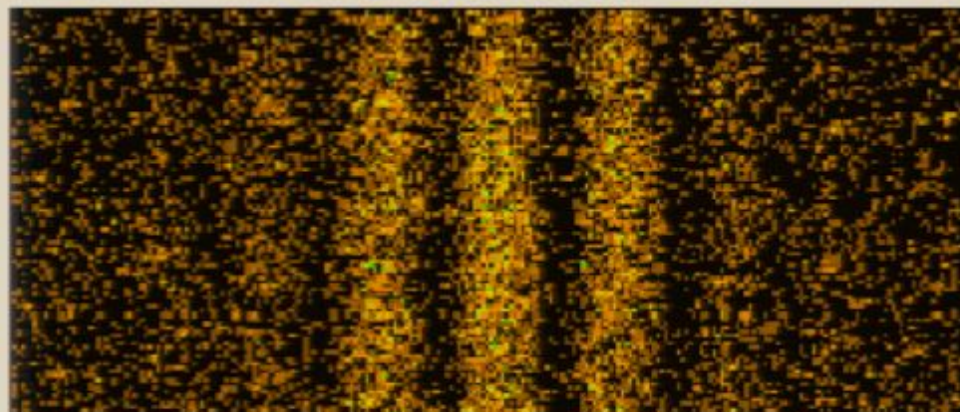
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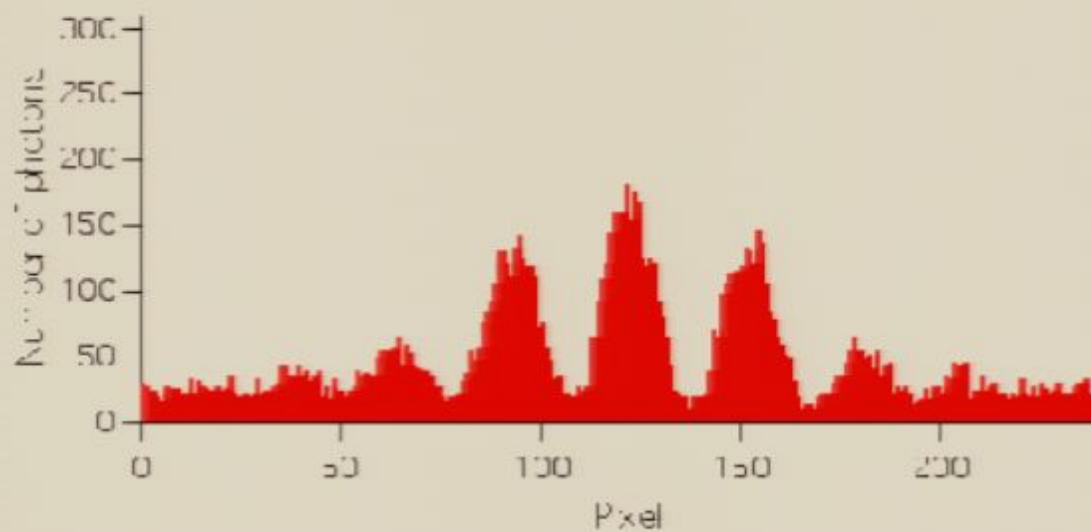
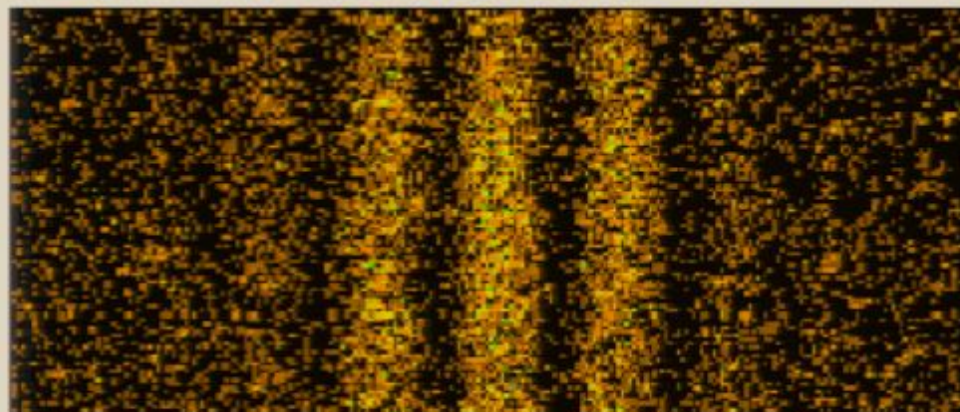
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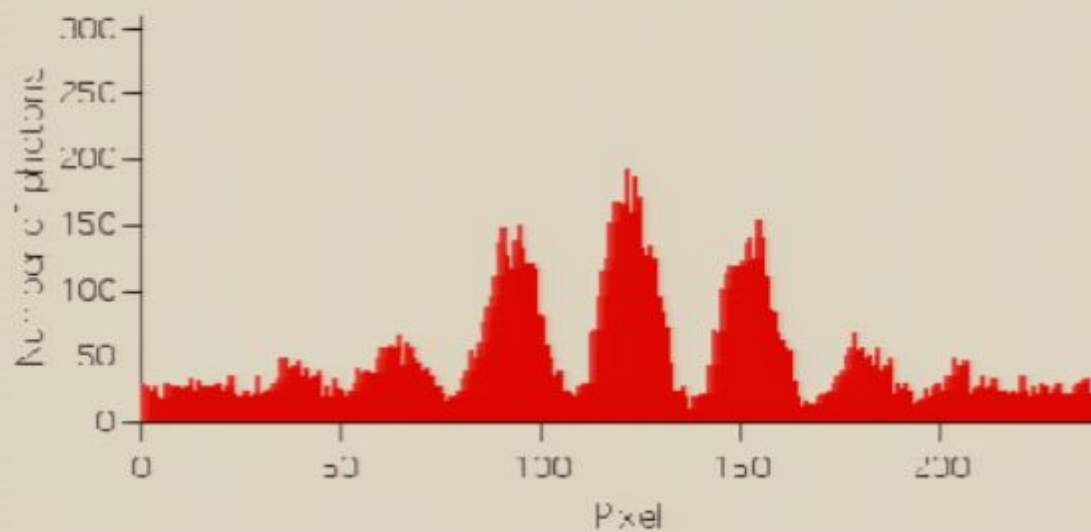
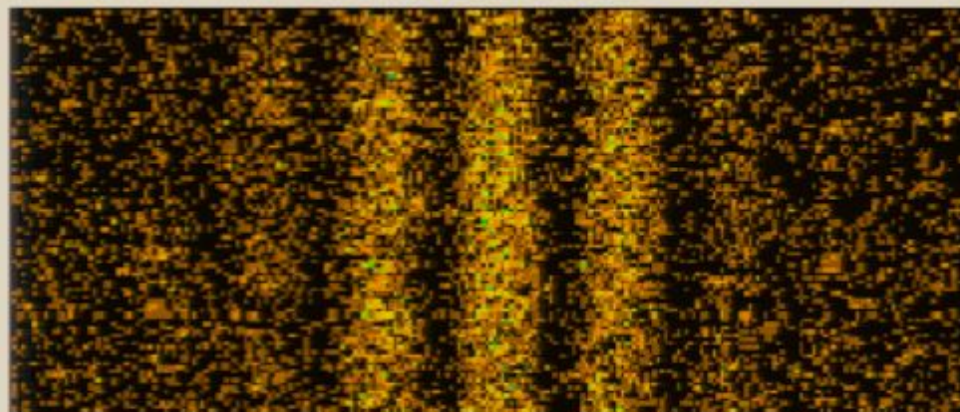
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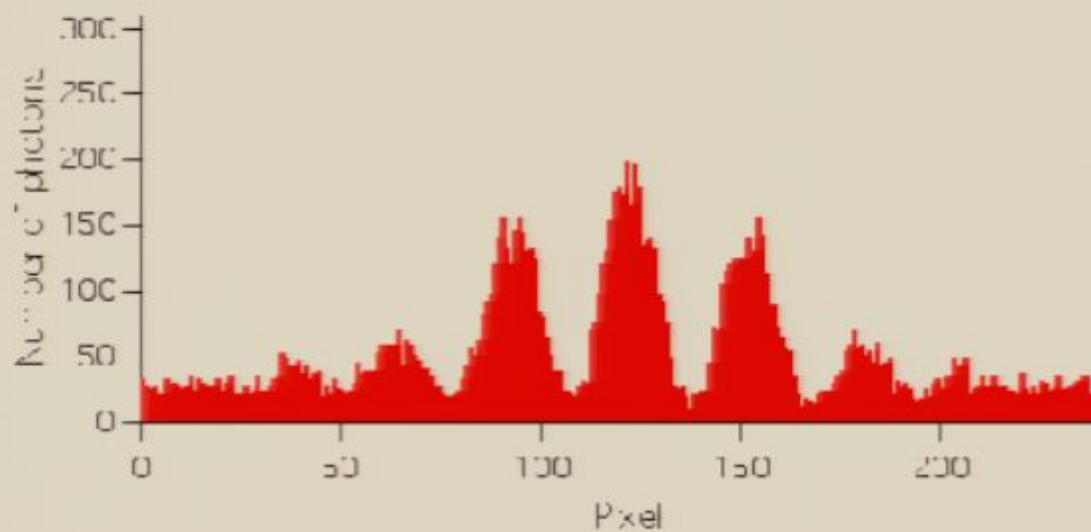
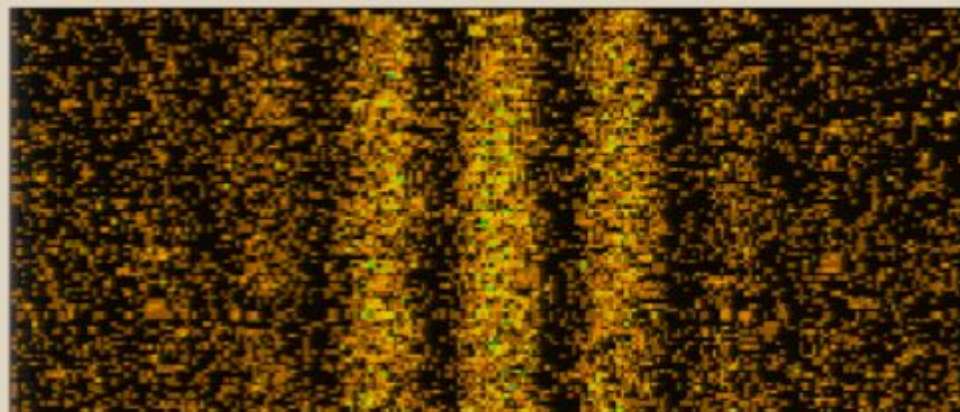
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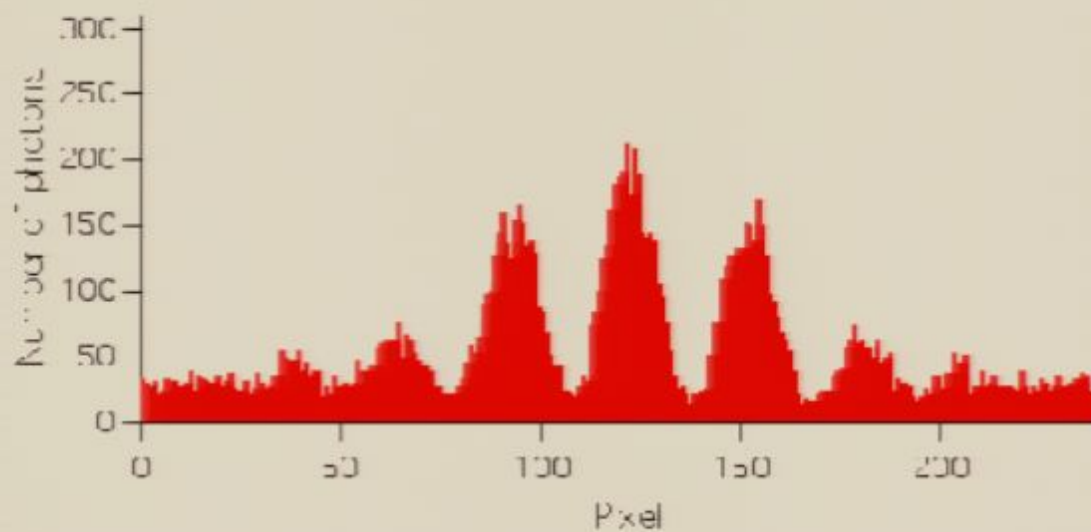
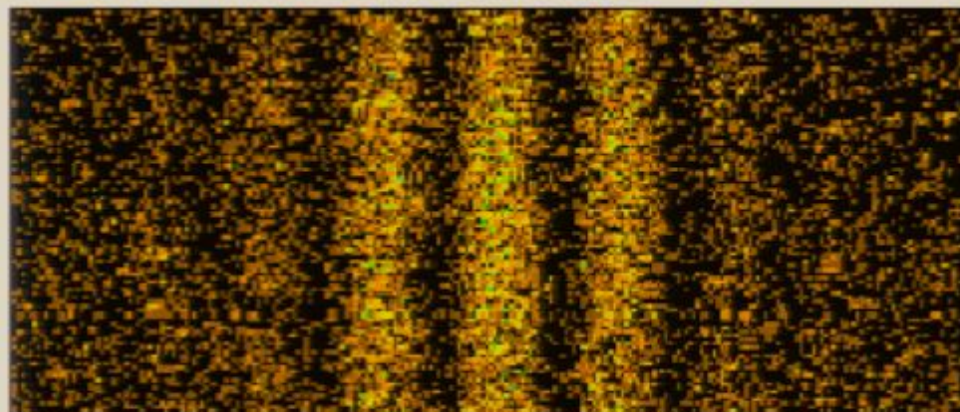
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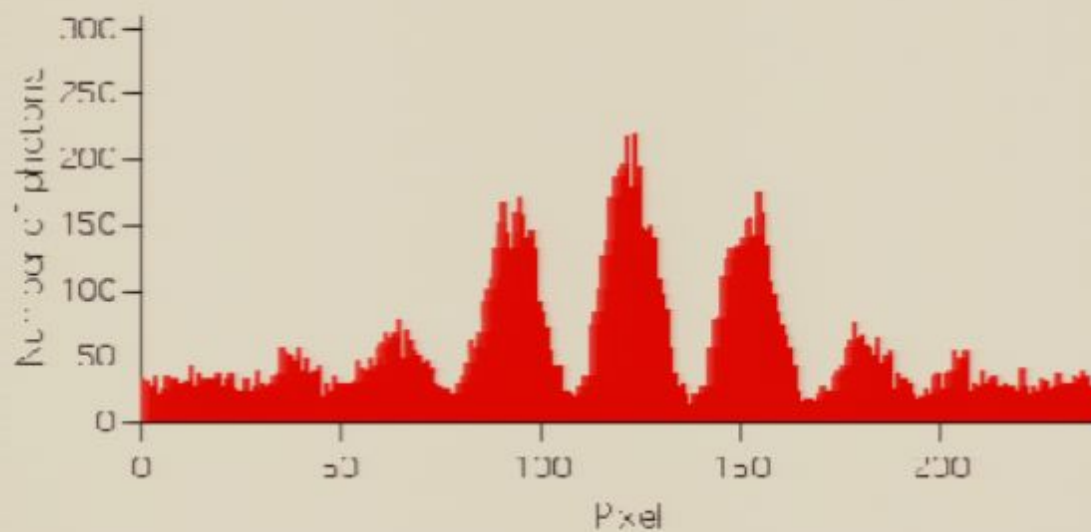
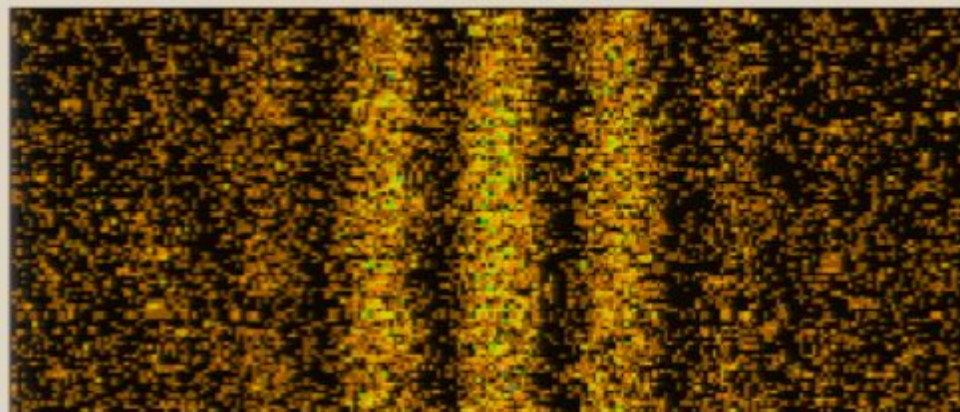
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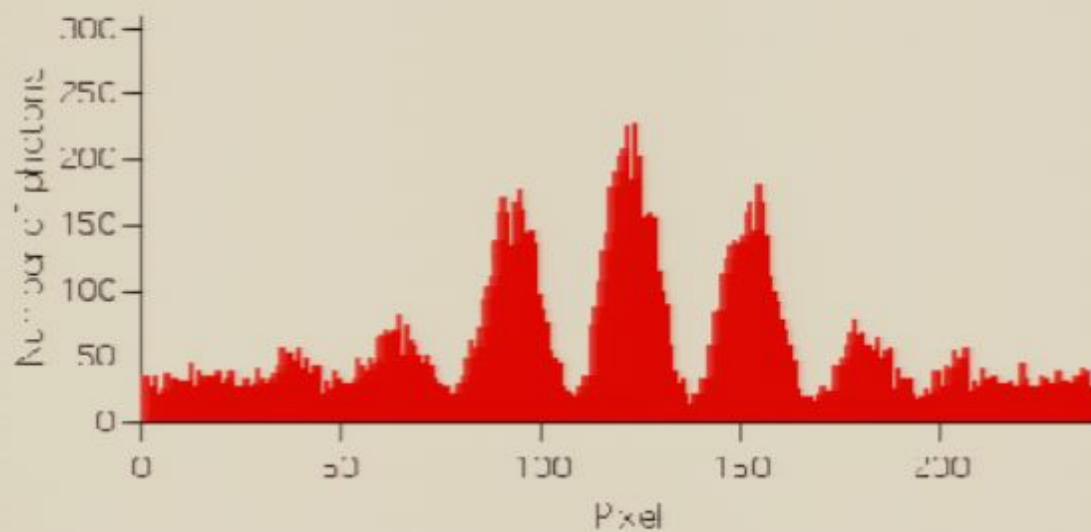
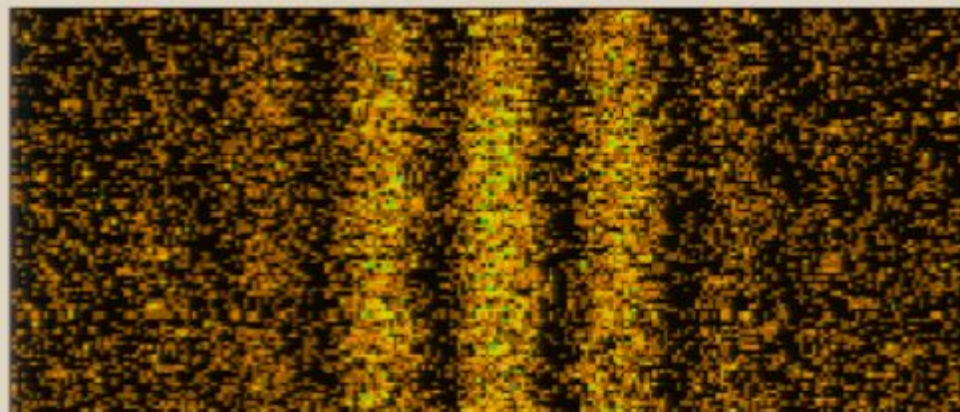
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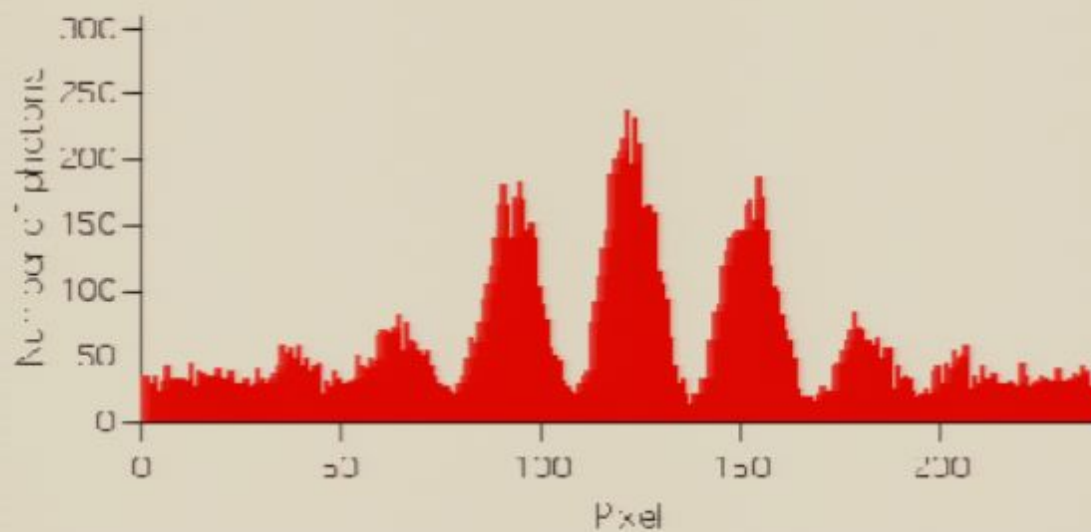
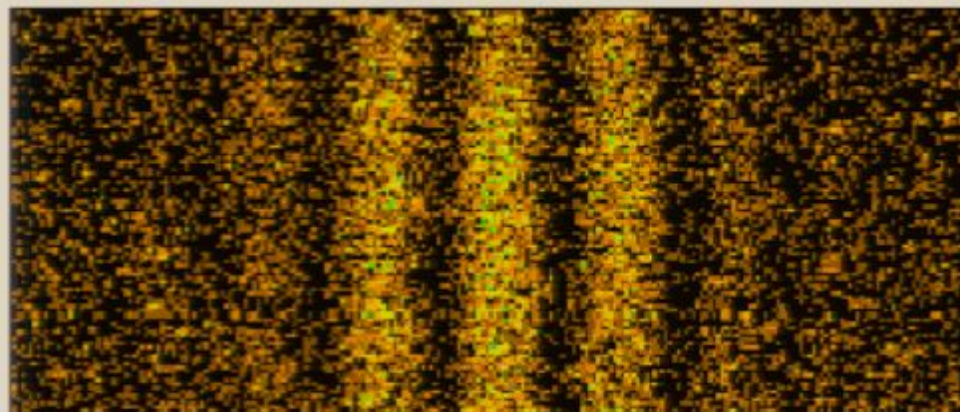
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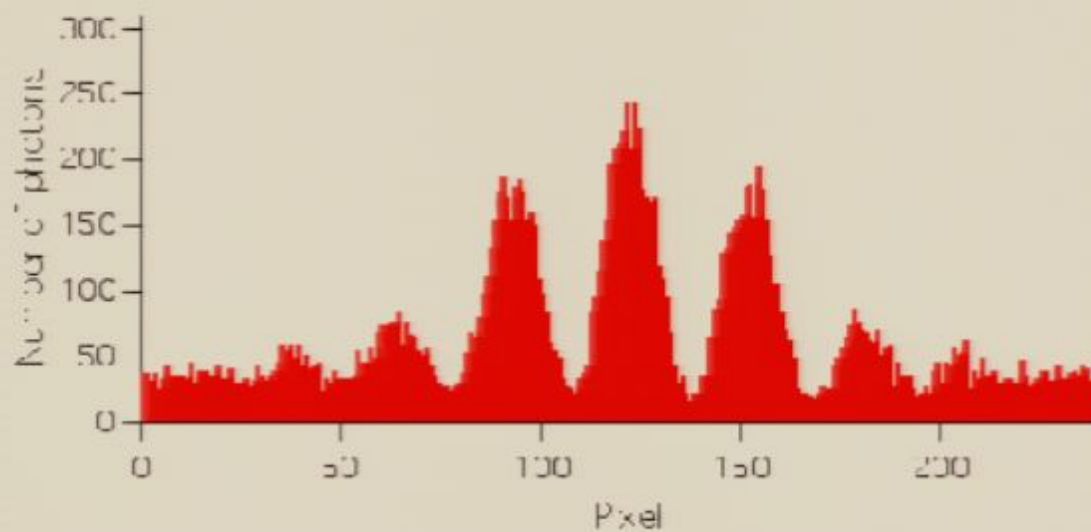
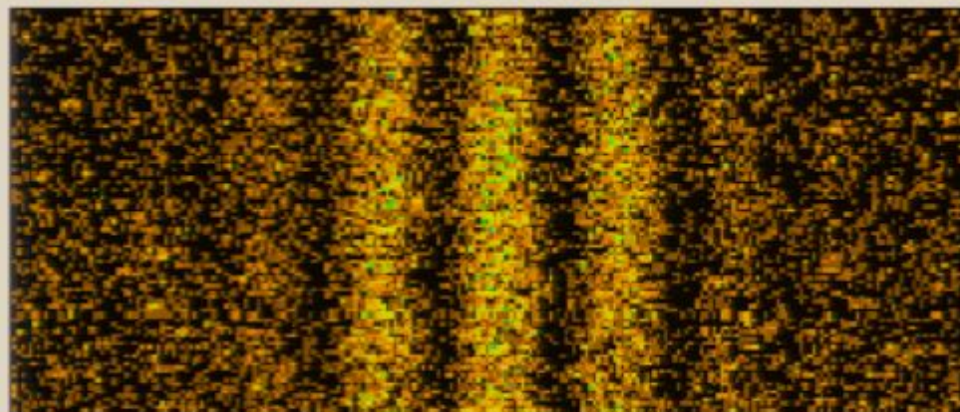
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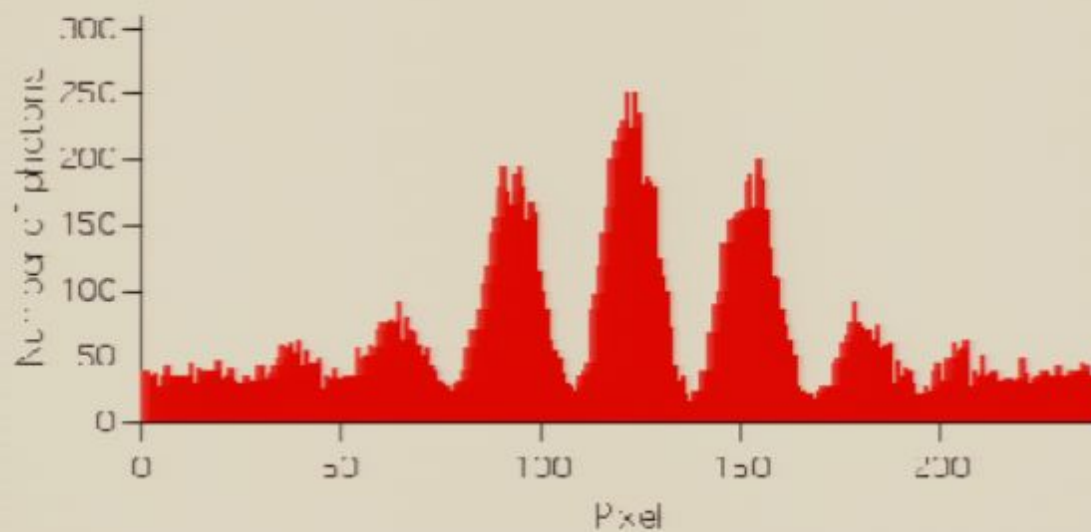
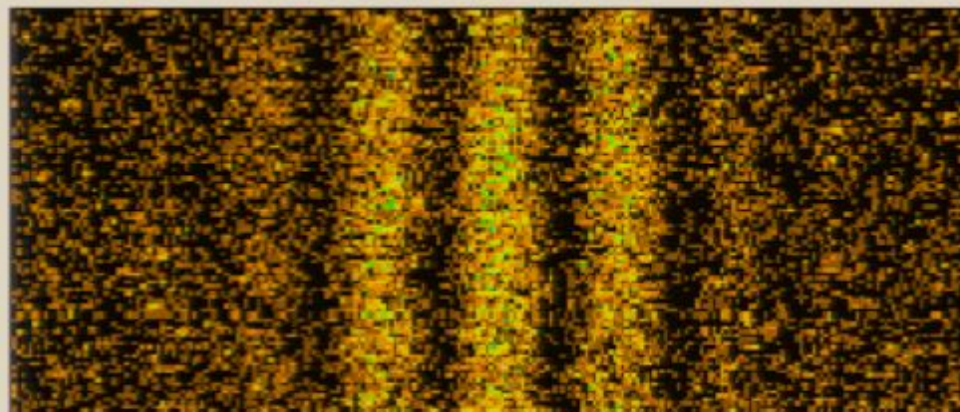
- Future directions : double slit experiment



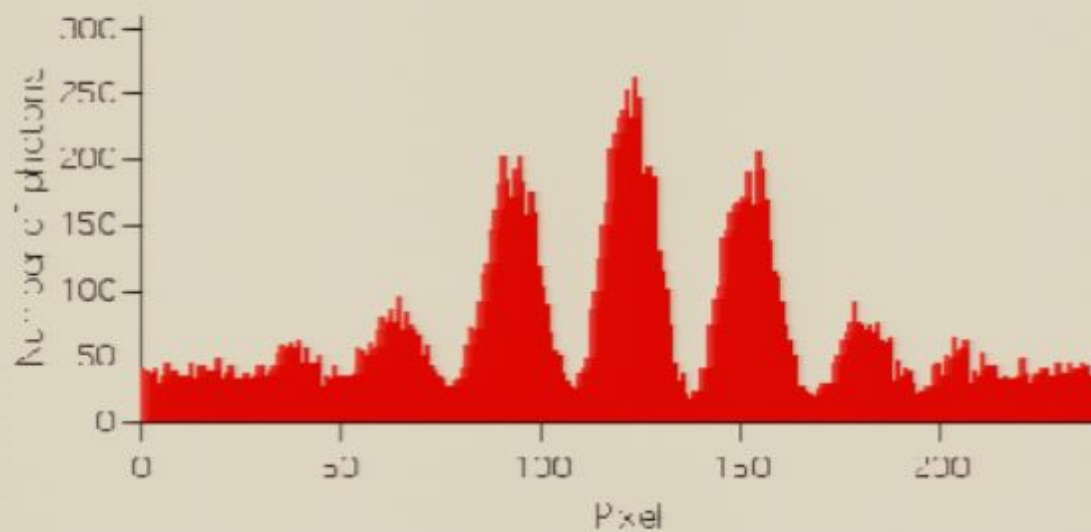
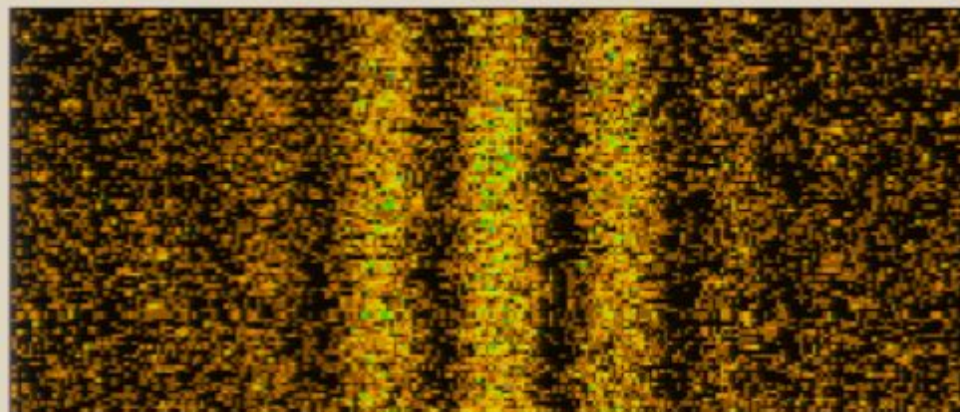
- Future directions : double slit experiment



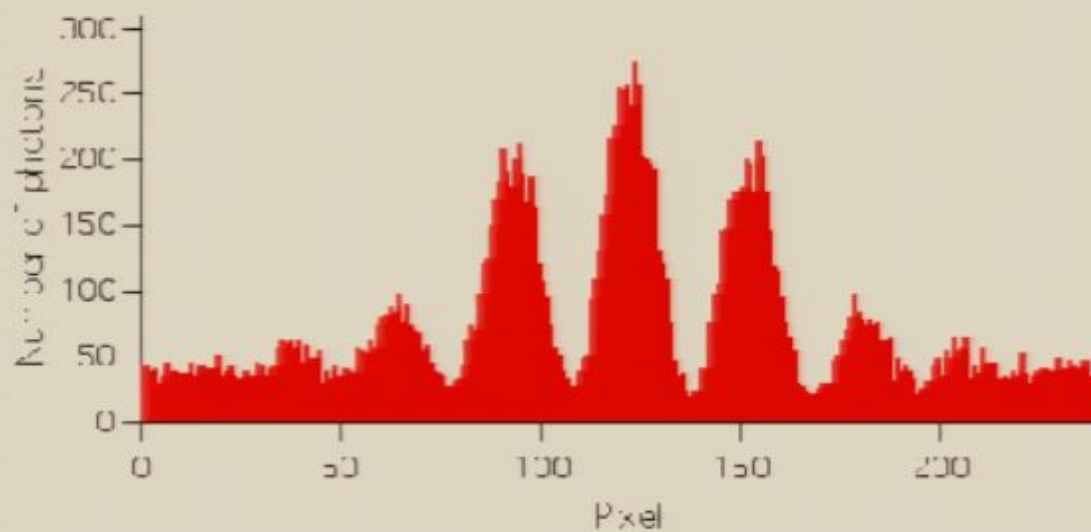
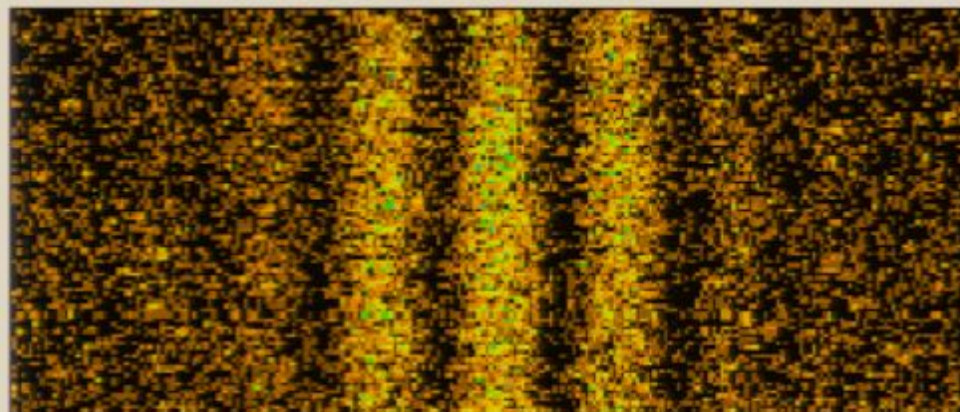
- Future directions : double slit experiment



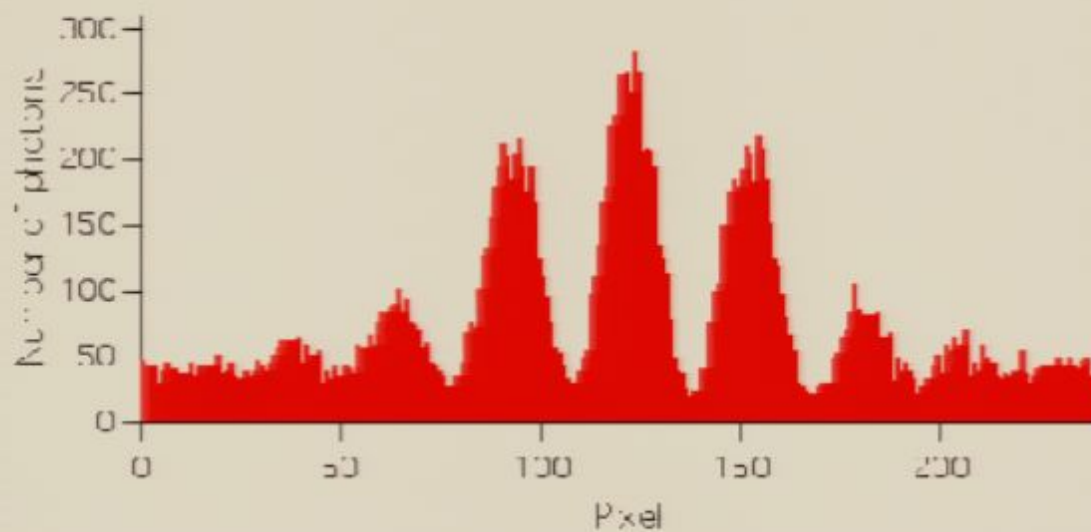
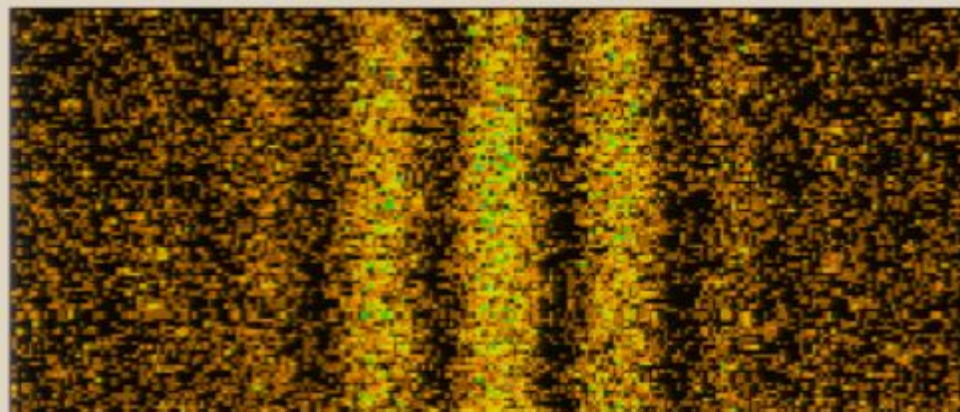
- Future directions : double slit experiment



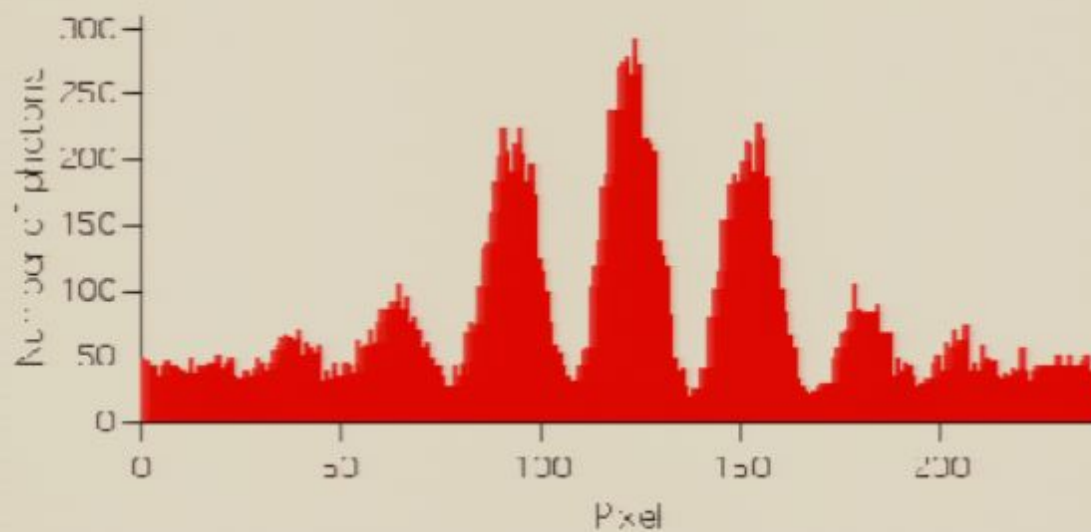
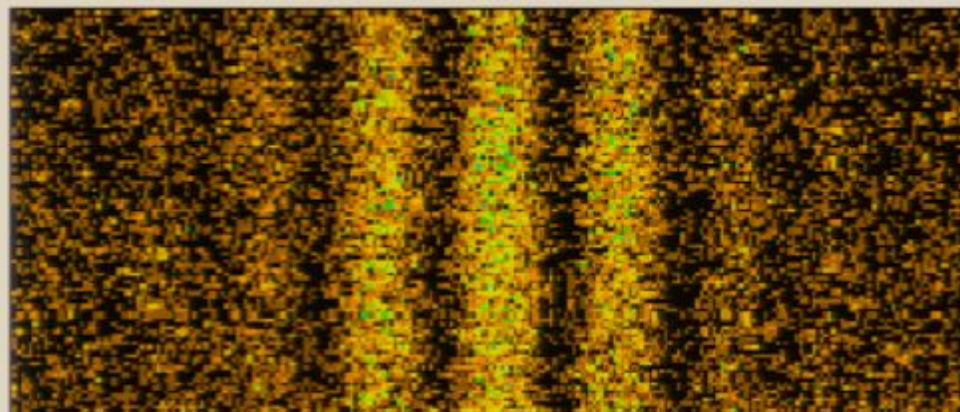
- Future directions : double slit experiment



- Future directions : double slit experiment



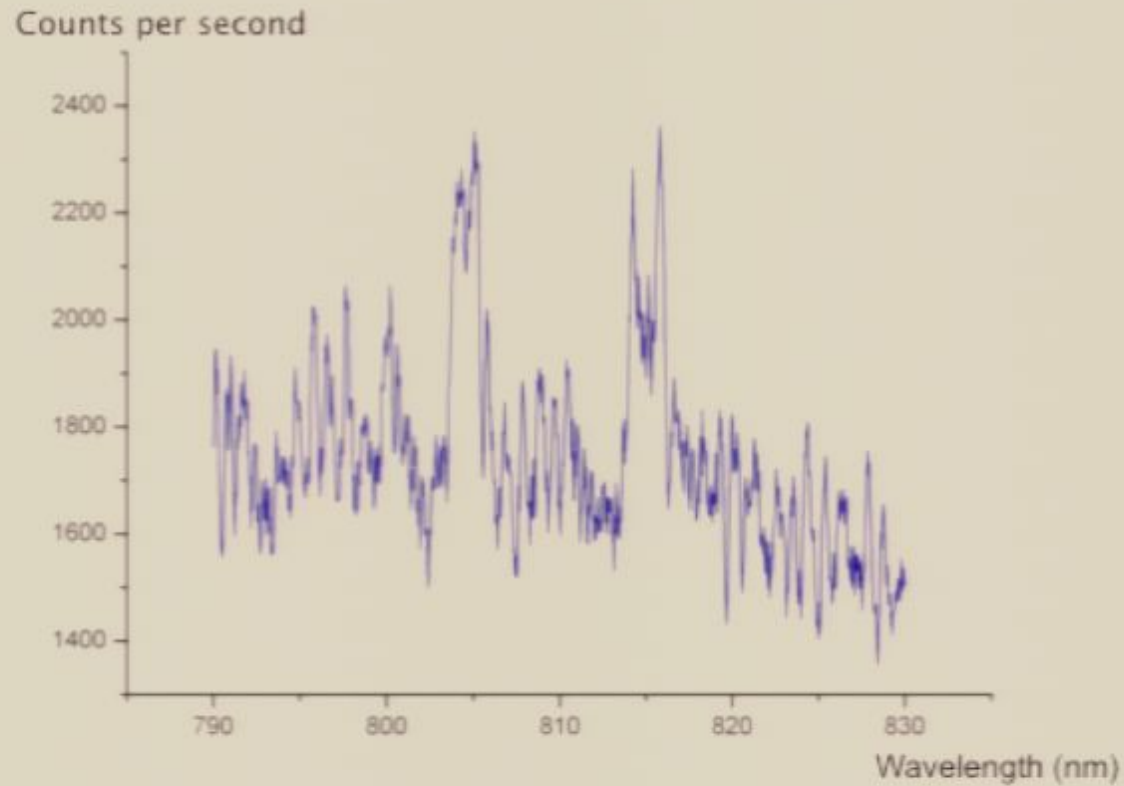
- Future directions : double slit experiment



Thank

Thank you !

- Next step
 - Find the red photons



- Plot the $g^{(2)}$ function
- Study the statistics of the source