Attophysics Science

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Light is one of the most precise tools we have to investigate matter. Its dynamics are so fast that we need adequate temporal resolution: at atomic level everything happens so quickly that we need a very fast camera. This camera is optical spectroscopy. The first spectroscopes were made with a continuous light source and a mechanical shutter that allowed microsecond flashes. It was the invention of pulsed lasers that revolutionized spectroscopy and allowed us to observe much faster dynamics.

In the 1960s, thanks to the Q-switching technique, pulses of the order of the nanosecond were obtained. In the 1970s the picosecond was reached, a thousand times shorter, later surpassed by the femtosecond.

In 2023 the Swedish Academy awarded the Nobel Prize for Physics to Pierre Agostini, Ferenc Krausz and Anne L'Huillier: "for experimental methods that generate attosecond pulses of light for the study of electron dynamics in matter". The history of this Nobel begins in 1987 when L'Huiller discovered that from the interaction between a noble gas and a beam of laser light, light waves at different wavelengths are produced, thus laying the theoretical foundations for the creation of pulses very short lights. At the beginning of the 2000s, the research groups led by Agostini and Krausz, in parallel and with different experimental setups, managed to produce a laser capable of emitting light pulses of 250 and 650 attoseconds respectively, also managing to measure its length.

To arrive at such short radiation pulses it was necessary to address a series of technological problems, starting with the development of detection systems capable of measuring such fast signals. But thanks to such impulses in the future it will perhaps be possible, rather than following the processes inside the atoms, to even influence their development: in electronics it will be possible to understand and control how electrons behave within a material. In the medical field it will be possible to exploit attoseconds to better understand the nature of certain molecules, thus obtaining highly specific diagnoses.

Just to give you an idea of the great impact that the creation of ultrafast pulses has had, it is enough to remember that attosecond physics has already proven to be an excellent tool in atomic physics, for investigation of electron correlation effects, photo-emission delay and ionization tunneling. In molecular physics to study the role of electronic motion in molecular excited states, light-induced photo-fragmentation, and light-induced electron transfer processes. And finally in solid-state physics, for the investigation of exciton dynamics in advanced 2D materials, petahertz charge carrier motion in solids, spin dynamics in ferromagnetic materials.

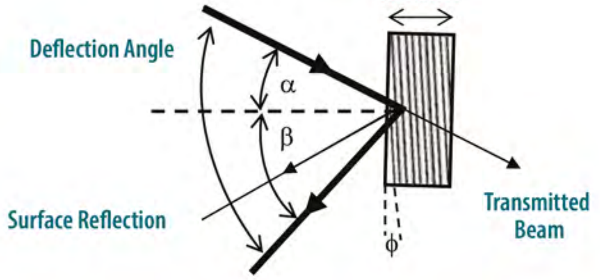
In 2019 we dedicated the second volume of EPN to the invention of the laser, and once again we are here to celebrate it. Lasers are closely linked to 13-14 physics prizes, involving new discoveries, inventions or research methods.

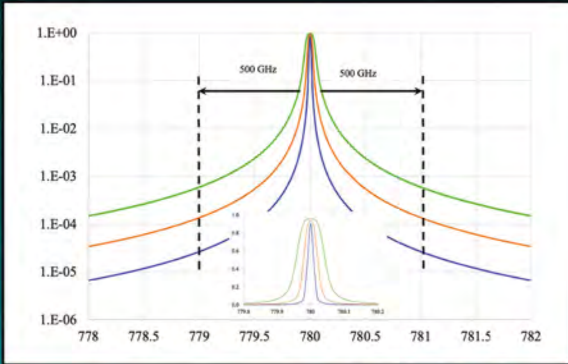
This year's Nobel Prize in Physics rewards not only the scientific genius of three researchers, but also the history of a technology and of the theoretical and experimental effort that has been made to bring it to the limits of the feasible, becoming the tool that will lead us to a deeper understanding of the behavior of matter. ■

Volume Bragg Gratings (VBGs) for
Quantum Optics

Available wavelength range: 600-2500 nm
Standard Wavelengths: 780; 795; 852; 894 nm
Standard Bandwidths: 10; 25; 50 GHz
Diffraction Efficiency: > 95%
Unmatched side-lobes suppression: > 50 dB

Parameters of 25-GHz Filter:
Spectral Bandwidth: <25 GHz;
Efficiency: >92%;
Attenuation: > 30 dB at >150 GHz shift



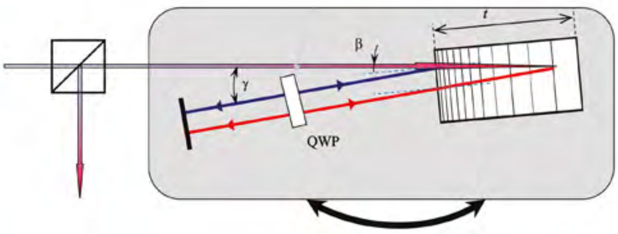


Spectral Shape of Reflecting VBG Filters with Bandwidth:
10 GHz; 25 GHz and 50 GHz

Chirped Bragg Gratings (CBGs) for
Qubit Control

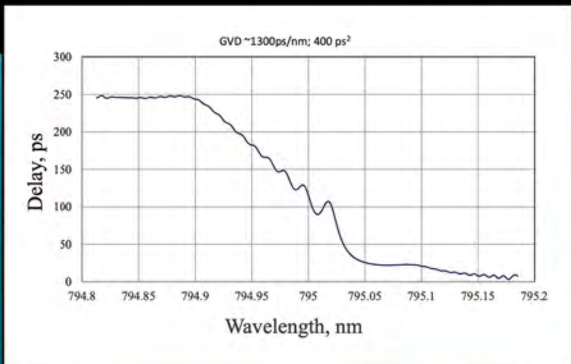
Extremely Large Dispersion 800 ps^2 enables effective and fast amplitude modulation

Spectral Range: 530-2500 nm; High Efficiency> 95%; Wavelength Tunable



Schematic Diagram of CBG deployment for Qubit Filtering and Control

Group delay dispersion of Chirped Bragg grating (CBG)



PTR glass based highly dispersive CBGs enabled passively stable, efficient, method of fast amplitude modulation compatible for high power laser sources. *[H. Levine at al. "Dispersive optical systems for scalable Raman driving of hyperfine Qubits," Phys. Rev. A 105, 032618 (2022)]*

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