

VELOCITAS[>]_{VMI}

Complete Solutions for Velocity Map Imaging



From

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ENVISAGE THE FUTURE

Velocitas VMI from Photek

Velocity Map Imaging (VMI) is a powerful experimental technique used in laser physics and physical chemistry research to investigate gas phase ionisation, fragmentation dynamics, photoelectron spectroscopy and much more.

VMI provides details on velocity, angular distribution and mass of charged particles, offering more complete information than many standard ion imaging and spectrometry techniques.

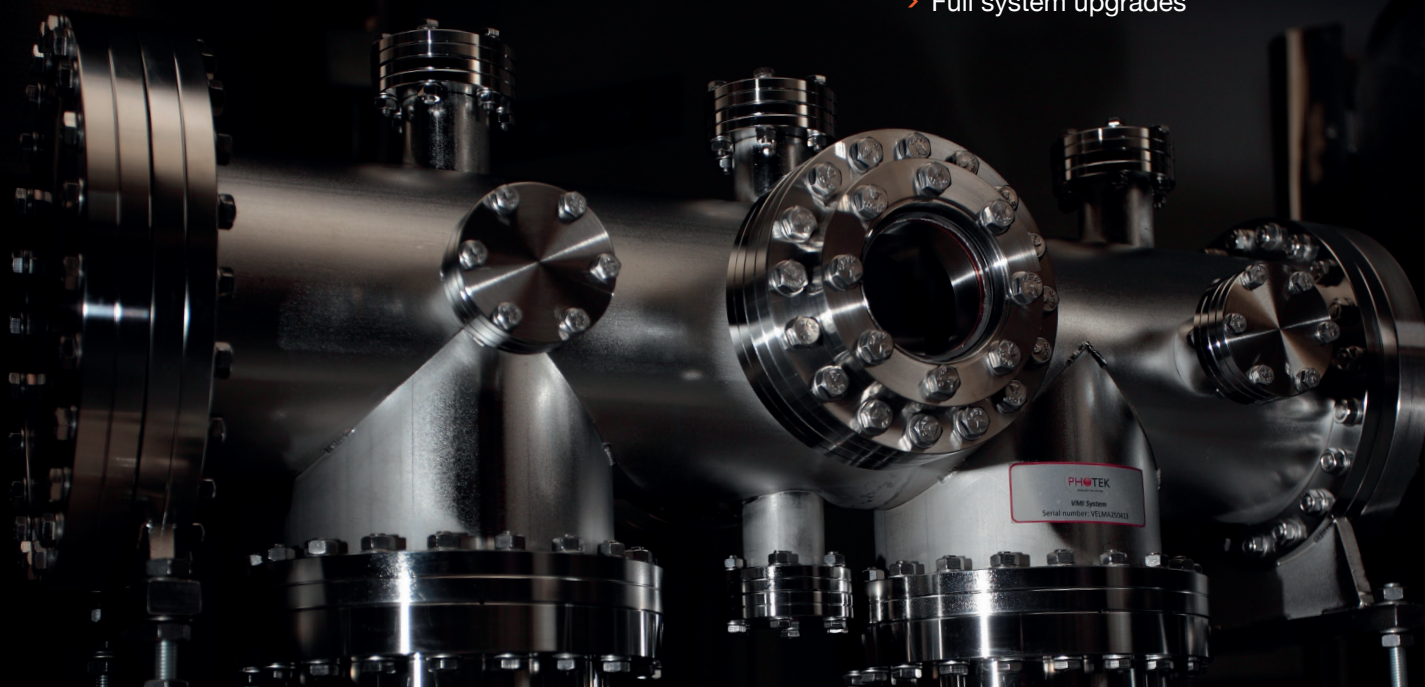
With rapid advances in charged particle detection and laser technology in recent years, velocity map imaging is becoming an even more popular technique in research laboratories worldwide. To support this developing market, we have collaborated with internationally renowned physical chemists and laser physicists to develop a range of VMI instrumentation and accessories to provide advanced VMI capabilities in various research laboratories.

We recognise the need for custom solutions to fit individual experimental needs, so the Velocitas VMI Spectrometer has a unique modular design with customisable components.

The bespoke system can be offered as a complete spectrometer solution, while individual components are designed to be compatible with standard laboratory installations. This provides the possibility of retrofitting into existing experimental setups and the potential for full system upgrades.

Unique Solutions for your research

- > Full systems or component combinations
- > Modular design
- > User friendly
- > Fully customisable
- > Retrofit capabilities
- > Full system upgrades



> Quality and Support

Velocitas VMI, from Photek Limited, is ISO 9001:2008 Certified so has quality systems in place to ensure your product is manufactured to the most exacting specification. We offer a twelve month warranty as standard and provide support for the lifetime of our products.

In the unlikely event that something does go wrong with your Velocitas VMI, we will ensure that it is repaired quickly to minimise downtime.

At Velocitas VMI, we pride ourselves in the support we provide to all our customers and our expert team of scientists and engineers have the capability to understand your application and provide you with the right solution. In addition, the Velocitas VMI product specialists can visit you on site to help with the installation of your spectrometer and provide full training.



Installation and Training

With each customer, we coordinate a delivery schedule involving installation, commissioning and on-site training. Commissioning experiments are tailored to match the characteristics of the customer's laser. Concurrently with the commissioning experiments, we train the end users on standard operating procedures for:

- > VMI ion optics
- > MCP detector
- > Camera and software
- > Pulsed valve
- > Vacuum system
- > Electronics and controls
- > Maintenance

Custom Development

Photek has the knowledge and resources to develop a custom product for your unique application, where our team of expert scientists and engineers have over 20 years of experience. Our team will work with you at every stage of the development process, including:

- > Initial discussion of the application and the type of product that meets your requirement
- > 3D CAD design
- > Prototype and product development
- > Product manufacturing and test requirements
- > Delivery schedule

> Spectrometer System

The Velocitas VMI Spectrometer is offered as a complete solution tailored for your research laboratory, or as individual components for upgrades to your existing experimental setup.

The system incorporates VMI ion optics with a pulsed valve, skimmer, flight tube and vacuum imaging detector, all housed in a bespoke, differentially pumped vacuum chamber. The chamber and vacuum pumps are neatly mounted on a single frame, with height adjustment and optional mobility in the laboratory. The spectrometer is completed with high voltage power supplies, electronics and controls for the detector, camera, ion optics, valve and vacuum system, along with a computer.

The only further requirement in the lab is a target gas supply and an ionising laser.

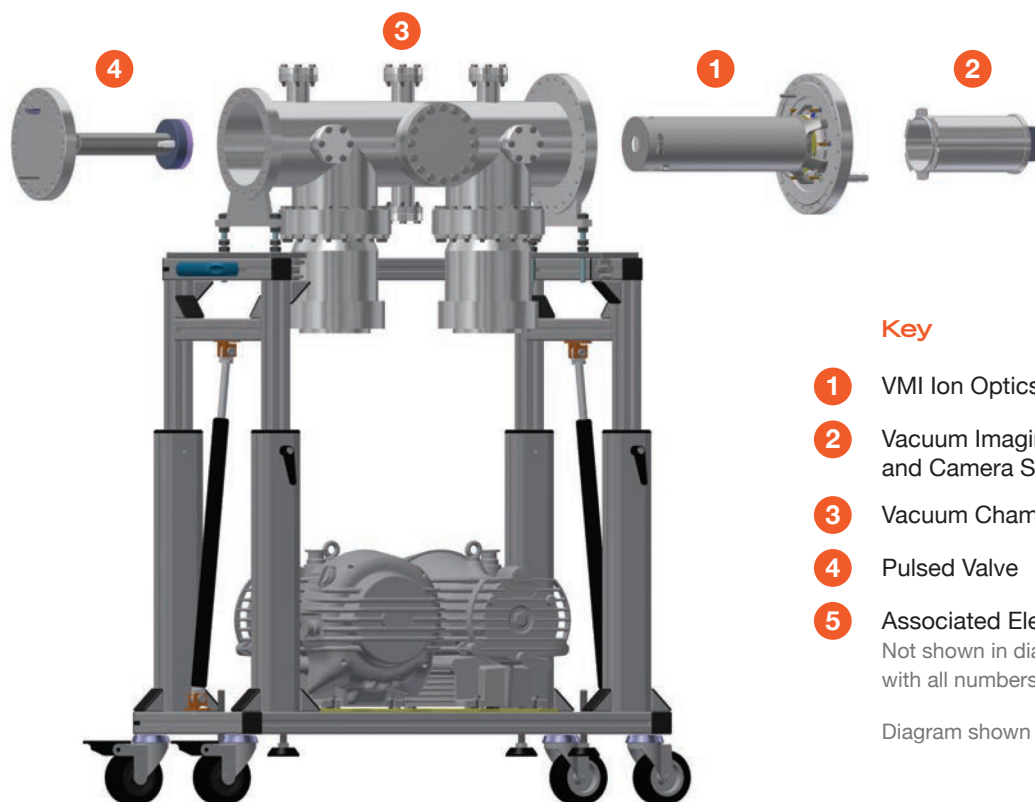
Our expert team of scientists and engineers have many years' experience in advanced detector development and bespoke system design. We have a long history of working with world-class research institutions and ultrafast laser laboratories, and we understand the demands of the modern day researcher.

Through our collaborations we have developed the state-of-the-art Velocitas VMI instrumentation and we continue to engage with current research topics in order to provide innovative technology solutions to facilitate new, demanding research applications.



Velocitas VMI instrumentation has been used in internationally renowned research institutions, including:

- > **Max Born Institut, Berlin**, in partnership with Prof Marc Vrakking, to investigate above threshold ionisation and time resolved IR-XUV spectroscopy of atoms.
- > **University of Bristol, UK**, in partnership with Prof Mike Ashfold to investigate resonant one-colour and two-colour photoionisation of diatomic molecules, with dc slicing for efficient data analysis.
- > **Sandia National Laboratory, California**, in partnership with Dr David Chandler, to investigate photodissociation properties of small molecules.



Key

- 1** VMI Ion Optics
- 2** Vacuum Imaging Detector and Camera System
- 3** Vacuum Chambers and Pumps
- 4** Pulsed Valve
- 5** Associated Electronics
Not shown in diagram but associated with all numbers part 1 - 4.

Diagram shown not to scale.

Part 1: VMI Ion Optics

We have a choice of ion optics for a range of experimental needs, including high resolution imaging, high energy photoelectron imaging or VMI with dc slicing. The ion optics have configurable options including different mounting possibilities, optional flight length and mu-metal shielding for optimal operation. Velocitas VMI ion optics have dual polarity, giving you the choice to image positive ions or electrons and negative ions, all with the flick of a switch. See pages 7-10.

Part 2: Vacuum Imaging Detector and Camera System

Our Vacuum Imaging Detector typically consists of open-faced MCPs and phosphor screen in vacuum, with external camera and image processing software. The detector can be configured for your specific application, with a choice of active area size, MCP gain, choice of phosphor, as well as additional TOF and MCP gating options. See pages 11-13.

Part 3: Vacuum Chambers and Pumps

The system typically incorporates more than one differentially pumped vacuum chamber (source chamber and interaction chamber). The vacuum chamber(s) design

can be tailored for your specific applications, including the option of laser access from more than one direction and extra ports for vacuum accessories, all neatly contained in a single frame. See page 15.

Part 4: Pulsed Valve

To efficiently and reliably deliver your target gas from the source chamber to the interaction chamber, we offer a choice of pulsed valves, with configurable options depending on your specifications including target density, molecular beam temperature and repetition rate. See page 14.

Part 5: Associated Electronics and Components

To complete the system, we include all required electronics: high voltage, ultra-stable, reverse polarity power supply units for the ion optics; power supply unit with tracking for the detector; MCP gating module; controllers for the pulsed valve and vacuum system; signal delay generator to co-ordinate timing between your laser system, the pulsed gas, detector gating and imaging camera; computer with Photek's established Image32 image processing software. See page 15.

Applications

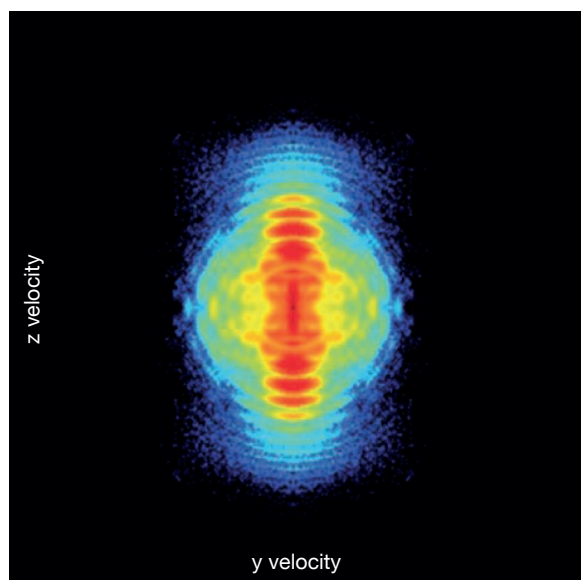
The Velocitas VMI Spectrometer can be used with laser pulse durations from nanoseconds to attoseconds and photon wavelengths from IR to XUV and X-ray.

Capturing 3D information on kinetic energy, angular distribution and signal intensity, the spectrometer can be used as a diagnostic tool in femtosecond and attosecond laser characterisation, or in fundamental investigations of electron processes, stereochemistry and photodissociation dynamics.

VMI is an increasingly popular technique in a wide range of research laboratories. We aim to understand your specific application to be able to offer a bespoke spectrometer design to fit your individual needs.

Find links to research on our website:

www.velocitas-vmi.com



Above: VMI of photoelectrons from ATI of Xe at $1 \times 10^{14} \text{ Wcm}^2$. With permission from MBI, Berlin.

Specific examples of Velocitas VMI applications include:

> Photoelectron Spectroscopy

Photoelectron spectroscopy provides fundamental information on electronic structure in atoms and small molecules, playing an integral part in investigations into electron dynamics and coherent control.

> Attosecond Laser Characterisation

By observing the intensity and angular distribution of photoelectron interference patterns from XUV-IR photoionisation, the relative phase is known and the electric field of attosecond pulses can be reconstructed.

> Photodissociation Dynamics

Imaging the 3D velocity distribution of state-selected reaction products helps build a picture of molecular stereodynamics and how it affects chemical reactions and energy transfer processes.

> Time Resolved Dynamics

Fundamental dynamical processes can be characterised by recording photoelectron and/or photoion kinetic energy distributions for different delays in pump-probe spectroscopy experiments.

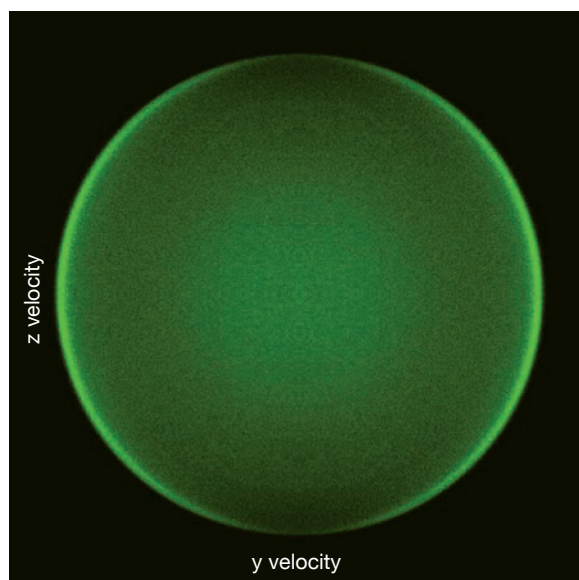
> Ion Optics

In Velocity Map Imaging, a charged particle is mapped onto a point on a two dimensional detection plane dependent only on the particle's nascent velocity vector.

The mapping is independent of the particle's starting position, which introduces a 'de-blurring' effect compared to standard ion imaging techniques. This makes VMI an incredibly powerful, high resolution experimental method.

High quality VMI is facilitated by carefully designed electrodes which define the shape of the electrostatic potential field. We have designed a series of VMI ion optics to suit a wide range of experimental requirements, from high energy photoelectron imaging to dc slicing in photoion imaging.

With the modular design of the Velocitas VMI instrumentation, the ion optics can be delivered as part of a full spectrometer system, or as a stand-alone component to upgrade an existing experimental arrangement.



Above: VMI of $^{79}\text{Br}^*$ from photodissociation of IBr.
With permission from University of Bristol.

The Velocitas VMI Ion Optics have a number of configurable options, including:

- > Variable operating voltages (up to ± 15 kV)
- > Choice of flight tube length (typically ~ 400 mm)
- > Optional mu-metal shielding for isolation from external perturbations
- > Choice of mounting configurations
- > Compatibility with a selection of detector sizes (typically 40 mm or 75 mm active diameter)
- > Optional gating of the detector (for dc slicing and mass selectivity)

Each ion optics design has universal applications in a huge range of VMI experiments.

Our dedicated development team are available to discuss the options to help determine which configuration is best for you.

> Design and Development

Velocitas VMI has in-house expertise on ion optics modelling and design, with extensive knowledge of Simion and MASIM 3D charged particle simulation software.

We are dedicated to the development of novel imaging applications and work closely with the research communities through collaborative research and training networks. Our past collaborations have included:

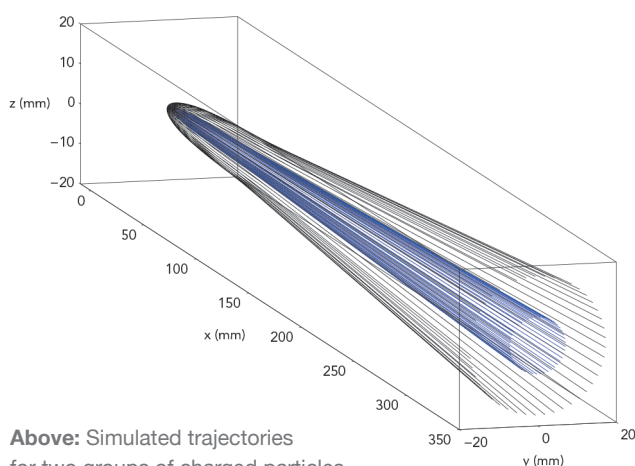
- > **Prof Mike Ashfold**, University of Bristol
- > **Prof David Parker**, Radboud University, Nijmegen
- > **Prof Marc Vrakking**, MBI, Berlin

Our collaborations have led to the development of a series of ion optics designs, each offering different functionality for optimum performance in the laboratory:

> PRIME

A classic assembly with three electrodes (Repeller, Extractor and Ground) specifically designed for high energy photoelectron imaging (up to 100 eV) in femtosecond and attosecond experiments.

Developed in collaboration with Prof Marc Vrakking at MBI, Berlin.



Above: Simulated trajectories for two groups of charged particles, where radius of detection (at $x = 350$ mm) is proportional to nascent velocity (at $x \sim 0$).

> DOUBLE PRIME

An innovative design with four electrodes (Repeller, Extractor, Lens and Ground), incorporating shaped Repeller and Extractor and stabilising electrodes for ultimate field definition and robust velocity mapping operation.

Developed in collaboration with Prof Mike Ashfold at University of Bristol.

> High Density

A pulsed valve is integrated into the Repeller to offer a much higher gas density at the laser focus. In attosecond photoionisation experiments, this provides an order of magnitude increase in signal intensity.

Developed in collaboration with Prof Marc Vrakking at MBI, Berlin

> Slice

An elongated acceleration region increases the arrival time of the Newton sphere at the detector. Coupled with the Velocitas VMI Vacuum Imaging Detector and Photek's Gate Module, this offers excellent slicing capabilities with high velocity resolution.

Developed in collaboration with Prof Mike Ashfold at University of Bristol.

Further design and development projects include:

- > An add-on zoom lens, offering up to $\times 10$ magnification of the ion image.
- > The option of advanced set-ups; for example, crossed molecular beam imaging.

Visit www.velocitas-vmi.com and contact us for more specifications, or if you have a development need that our expert team can help you with.

> PRIME Ion Optics

PRIME was designed in partnership with Prof Marc Vrakking and his research group at MBI, Berlin. The ion optics have been used in experiments investigating strong field interactions and time resolved dynamics of atoms, involving photoion and high energy photoelectron imaging.

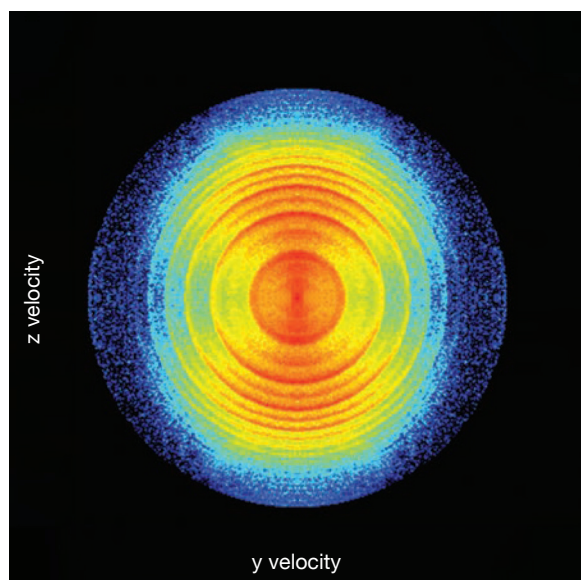
PRIME's classic design and dual voltage controls offers a user-friendly operation. The annular Repeller, Extractor and Ground are typically assembled with a stainless steel flight tube and outer mu-metal casing for shielding from perturbing fields. These features make PRIME ideal for photoelectron spectroscopy and laser characterisation experiments in femtosecond and attosecond laser laboratories.

PRIME has been used in numerous laser laboratories, including the Attosecond Physics laboratory at MBI, with proof of concept experiments including ATI and

two colour ionisation of atoms using IR and XUV photon sources. PRIME demonstrates the capabilities of velocity mapping of photoelectrons up to 100 eV, with a velocity resolution $< 2\%$.

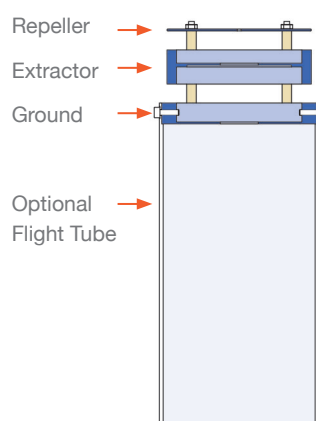
As with all the Velocitas VMI ion optics, PRIME comes with configurable options including:

Optional flight tube and mu-metal shielding, choice of mounting options and compatibility with a selection of detector sizes and vacuum chamber configurations.



Above: VMI of photoelectrons from two colour photoionisation of Ar (800 nm and harmonics 11-29 from HHG) in VMI PRIME. With permission from MBI, Berlin.

Cross section of Velocitas VMI PRIME



DOUBLE PRIME Ion Optics

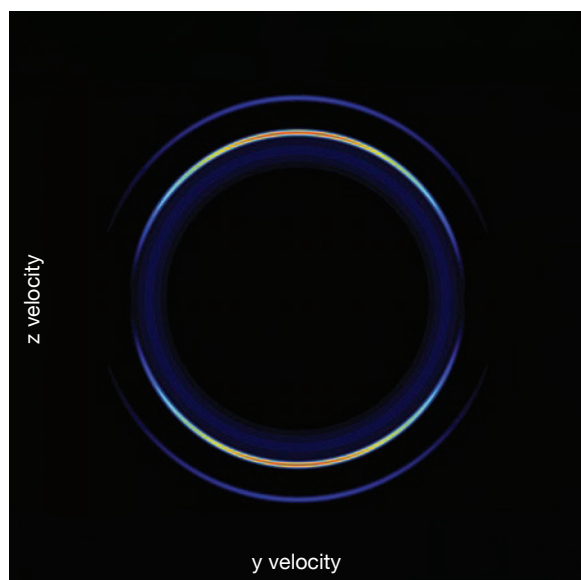
DOUBLE PRIME was designed in partnership with Prof Mike Ashfold and his research group at the School of Chemistry, University of Bristol. The ion optics have been used in experiments involving the photodissociation of small molecules, with the benefit of dc slicing for improved data analysis.

DOUBLE PRIME's advanced design offers a higher velocity resolution and increased ionisation volume compared to standard VMI ion optics. DOUBLE PRIME has an optimally-shaped Repeller and Extractor, an annular Lens and additional stabilising electrodes for ultimate velocity mapping field definition.

The state-of-the-art DOUBLE PRIME further offers the capability of dc slicing under standard velocity mapping conditions, negating the need for complex reconstruction algorithms to obtain energy and angular distribution information.

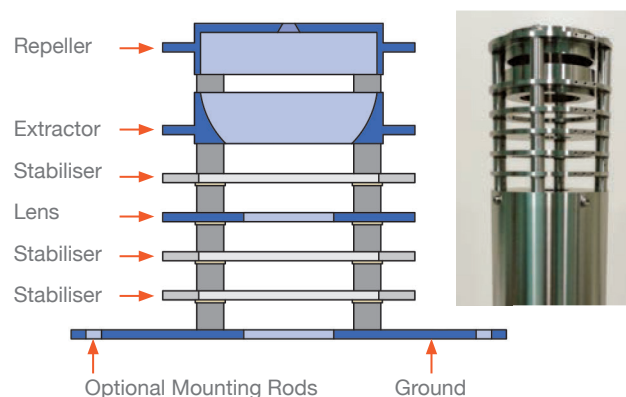
DOUBLE PRIME has been used in different laboratories, including the laser laboratory at the School of Chemistry, University of Bristol, with proof of concept experiments including one and two colour REMPI of diatomic molecules in state-selected imaging investigations. DOUBLE PRIME offers very high velocity resolutions approaching 1% limited mainly by inherent properties of the molecular beam.

As with all the Velocitas VMI ion optics, DOUBLE PRIME comes with configurable options including: Optional flight tube and mu-metal shielding, choice of mounting options and compatibility with a selection of detector sizes and vacuum chamber configurations.



Above: Inverted image from VMI of Br from photodissociation of IBr in VMI DOUBLE PRIME. With permission from University of Bristol.

Cross section of Velocitas VMI DOUBLE PRIME

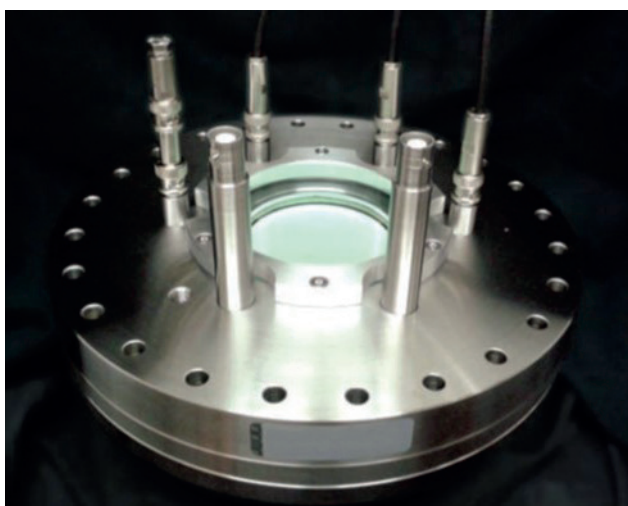


> Vacuum Imaging Detector

The Velocitas VMI Vacuum Imaging Detector (VID) is an open faced MCP detector, suitable for vacuum imaging experiments. The detector is usually mounted on a vacuum flange, ready to be secured to a vacuum chamber

The VID is designed to detect charged particles, UV photons and neutrons. For VMI applications a typical VID will have two MCPs and a phosphor screen, but the detector is also available with a solid anode for custom anode configurations. The phosphor screen can include a time of flight module, providing a timing response of 3 ns. With a Photek Gate Module, the operation of the MCP can be reduced to less than 10 ns, allowing dc slicing in VMI experiments.

We have a long history in the design and manufacture of Vacuum Imaging Detectors, with expertise in phosphor deposition, hardware manufacture and software development. We continually invest in new detection and imaging developments, including investigations of brighter phosphors and 3D imaging capabilities.



Features

- > High resolution
- > 18, 25, 40, 75 and 150 mm active diameter
- > One, two or three MCPs (for gain from 104 to >107)
- > Choice of flange size, with radial or axial feedthroughs
- > Optional MCP gating to 8 ns
- > Phosphor screen (P47, P43, ...), or electrical output
- > Optional TOF module, 3 ns FWHM
- > Resistive sea with re-configurable anode options
- > HV Power Supply
- > Custom CAD design

Applications

- > Ion imaging
- > dc slicing
- > Mass spectrometry
- > Photoelectron spectroscopy
- > Synchrotron radiation detection
- > VUV imaging
- > Space telescopes
- > Nuclear physics

Visit www.velocitas-vmi.com for more details or contact us about your specific applications.

> Camera and Image32 Software

The Velocitas VMI Vacuum Imaging Detector with phosphor screen can be supplied with a high resolution camera and Photek's established Image32 image processing and data acquisition software for a complete detection solution to your vacuum imaging experiment.

Along with in-house camera and software developments, we work with global manufacturers of digital cameras to provide you with the right detection capabilities.

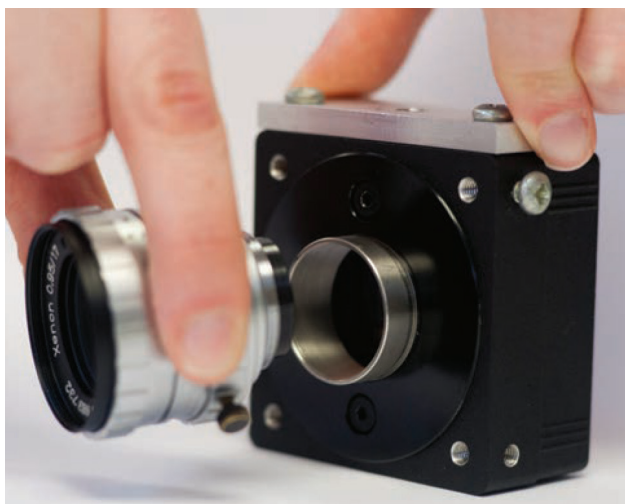
The specification of the camera is chosen to exceed the demands of your experimental application. The camera and lens assembly can be mounted on your detector flange in a configurable, light tight housing, for ideal operation in the laboratory. Image32 software has numerous operating modes, including centroiding and photon counting, with the option of control via other programming languages.

We offer our imaging software with a camera of choice to provide full detection capabilities in the laboratory. Our expert team of designers and engineers can also develop custom software and firmware solutions for individual applications.

Contact us or visit www.velocitas-vmi.com for more details.

Image32 image processing software features:

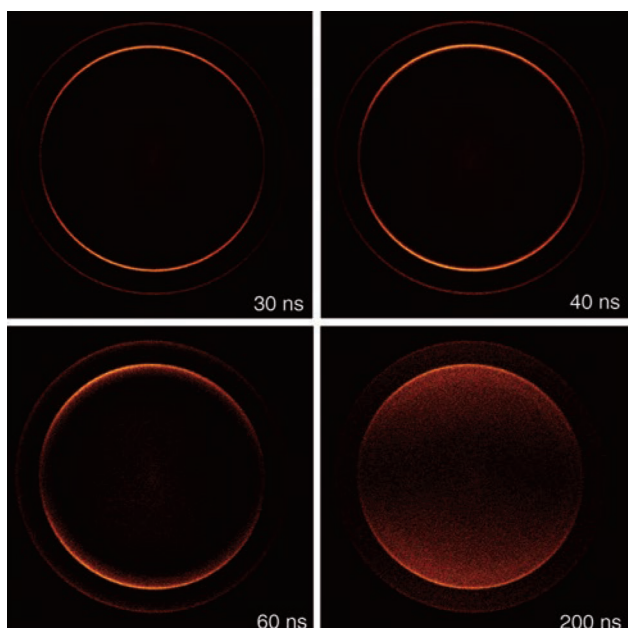
- > Simple user interface
- > Centroiding options
- > Photon Counting options
- > Background subtraction
- > Arithmetic functions
- > Compatibility with LabVIEW
- > Lua based control sequences
- > Range of data extraction and graphing routine
- > 8 bit, 16 bit, 32 bit, floating point or colour format images



> Gate Module

Photek's gate module enables gating of the MCP in a Vacuum Imaging Detector, allowing for mass gating, time resolved investigations and dc slicing in VMI experiments. The gate width can be varied from 8 ns up to a few microseconds.

The GM-MCP is designed to work with the Velocitas VMI Vacuum Imaging Detectors, where the input trigger will supply a 500 V pulse to the rear MCP, bringing the MCP from almost no gain to full operation for a user-defined time window.



Features

- > 8 ns FWHM minimum
- > Variable gate width
- > 500 V output pulse
- > 5 V trigger pulse
- > Up to 1 kHz repetition
- > Up to 3 kV offset voltage

Applications

- > Mass spectrometry
- > Velocity Map Imaging
- > Mass/isotope selectivity
- > dc slicing
- > Time resolved imaging
- > State-selected imaging
- > Detector protection from overload signal

Above Left: Photek Gate Module

Left: Slice images from VMI of Br from photodissociation of IBr in VMI DOUBLE PRIME, with gate widths of 30 ns, 40 ns, 60 ns and 200 ns (full Newton sphere). With permission from University of Bristol.

> Pulsed Valve

The Velocitas VMI pulsed valve is available as an individual unit, or flange mounted with the option of one, two or three dimensional manipulation. Choose from in-house designs or those from leading manufacturers, incorporating piezo actuators or solenoid based valves (e.g. Even-Lavie valve).

The valves can be operated at a range of frequencies and backing pressures, which can be tuned for any specific experiment. We have special designs for attosecond experiments, where the laser pulse can target the highest density gas for increased signal intensity.

At Velocitas VMI we are continually pursuing the development of new pulsed valve technology and improved target preparation tools, in collaboration with leading researchers and valve developers worldwide.

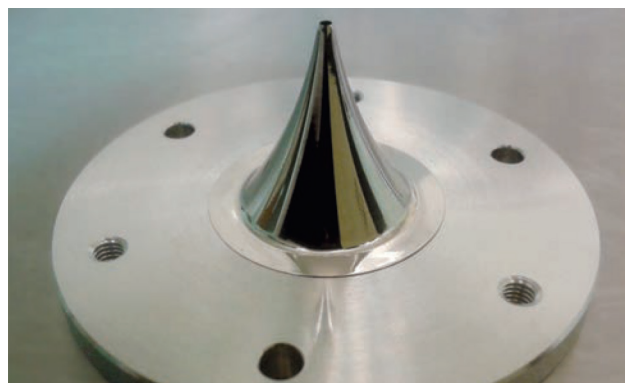
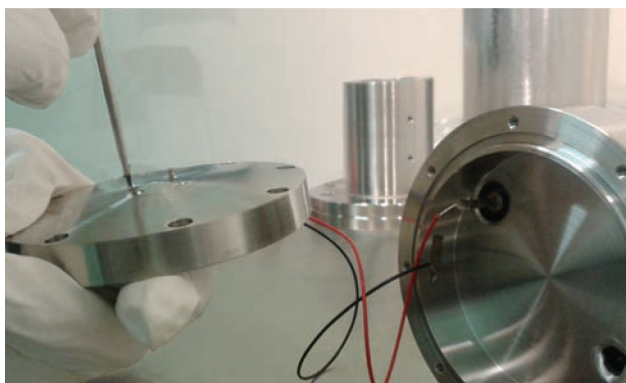
Visit www.velocitas-vmi.com for further information on our current technological developments and offerings.

Features

- > Vacuum compatible
- > High frequency (up to 1 kHz)
- > Short pulse widths (20 – 200 μ s)
- > High backing pressure (0 – 100 bar)
- > Cold molecules (10 K or less)

Applications

- > Molecular beams in vacuum
- > Velocity Map Imaging
- > Photodissociation
- > Attosecond science



➤ Electronics and Components

We have in-house expertise to design and manufacture many of the electronics and accessories associated with the Velocitas VMI Spectrometer. If we work with external suppliers, they are leading manufacturers in their fields. Visit our website and contact us if you have a specific software or hardware development need.

To complete the Velocitas VMI Spectrometer, we offer:

- Ion Optics Power Supply
- Vacuum Imaging Detector Power Supply
- Pulsed Valve Controller
- Bespoke Vacuum Chamber
- Turbomolecular Pumps and Controllers
- Vacuum Pressure Gauges and Controls
- Signal Delay Generator
- Computer
- High Resolution Time-to-Digital Converter
- Optional Cooling Accessories

Power Supply for Ion Optics

Ultra-stable, high-precision, reverse polarity bench power supplies, designed for ultimate operation of the Velocitas VMI Ion Optics. The units include multiple modules, depending on your requirements, with maximum operating voltages up to tens of kV (positive or negative). The supply is compatible with common programming languages for the option of user designed interfaces.

Power Supply for Vacuum Imaging Detector

Our bench power supply is specifically designed for Vacuum Imaging Detectors with one or two MCPs. Independent voltages are supplied to MCPs and Phosphor Anode, with features such as tracking for optimum control over detector gain and signal intensity. The supply is compatible with common programming languages for the option of user designed interfaces.

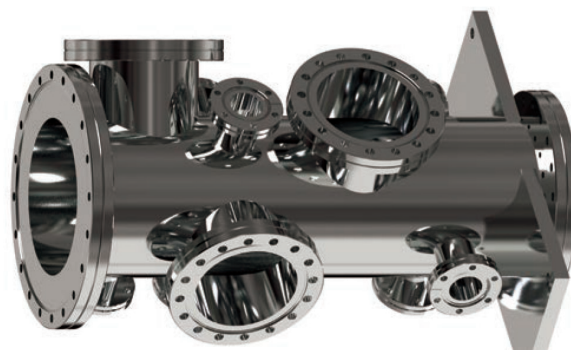
Pulsed Valve Controller

Our bench controllers are specifically designed to control the piezo and solenoid-based valves. The controller includes a trigger input, with variable rate and pulse width to determine the frequency and density of the target gas in vacuum. The controller is compatible with common programming languages for the option of user designed interfaces.

Vacuum Chamber and Accessories

We offer bespoke Vacuum Chambers and accessories to meet individual experimental needs, incorporating tailored designs of differentially pumped chambers with a choice of size and orientation of flanges.

This permits laser access from multiple directions, either through viewports or through vacuum, along with the addition of further vacuum accessories. We work with world leading manufacturers in vacuum technology to deliver the ultimate system for your experiment. The chamber and vacuum pumps are neatly mounted on a single frame, with height adjustment and optional mobility in the laboratory.



Above: CAD models illustrating our bespoke vacuum chambers which can be tailor made to fit your requirements.

About Photek

Photek is a specialist manufacturer of vacuum based tubes and camera systems for photon detection.

Our product range includes; Camera Systems, Image Intensifiers, Photomultiplier Tubes, Streak Tubes plus a range of associated electronics.

We are experts in large area and ultra-high speed imaging and advanced photon counting camera systems.

Our continuing success is built upon continuous innovation and product development, and by harnessing and applying knowledge to find solutions for all of our customers' applications.

Photek is accredited to ISO 9001 and ISO 14001.



Contact Us

Our team of specialist engineers and scientists are ready to discuss your application requirements in depth.

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