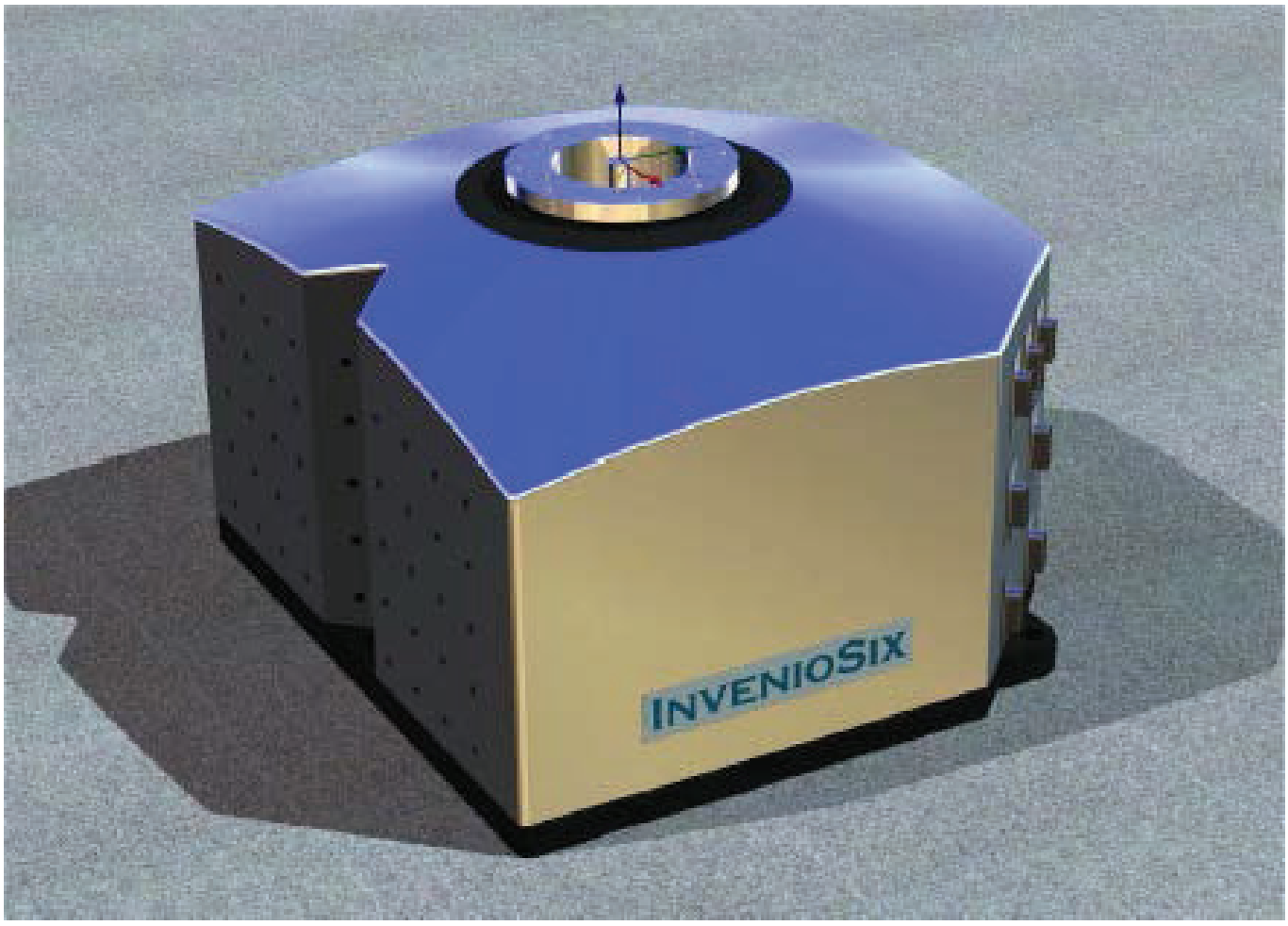
InvenioSix

The Six Degree of Freedom (6-DOF) Sub-Micron Precision Motion Platform



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Basic Description

InvenioSix is a general-purpose, 6-DOF motion platform for manipulating and aligning small payloads with sub-micron precision and high stability.

InvenioSix uses a revolutionary parallel-kinematics mechanism with significant performance advantages over stacked stage assemblies that have traditionally been used for generating 6-axis motions.

Furthermore, compared to parallel-kinematics systems made by other manufacturers, InvenioSix has superior robustness, higher thermal stability and higher load carrying capacity. The control software interface (InvenioSix PC), engineered by one of the world's leading experts in 6-axis robotics, can also be enhanced by adding the optional fully-integrated machine vision.

The powerful InvenioSix PC software's simple easy script language, with interpretive editor and code visual simulator, gives the user complete control over motion sequences, coordinate systems, and the location of the pivot point (i.e. axis of rotation).

Although the InvenioSix mechanism utilizes a fully closed-loop positioning system via six high-resolution encoders, alignments can be enhanced using additional real-time closed-loop feedback from analog inputs. Also, the optional integrated machine vision system, customer-specified instrumentation (via a GPIB / IEEE interface), or user provided dll's and hardware, can be used as a secondary sample rate closed-loop control scheme.

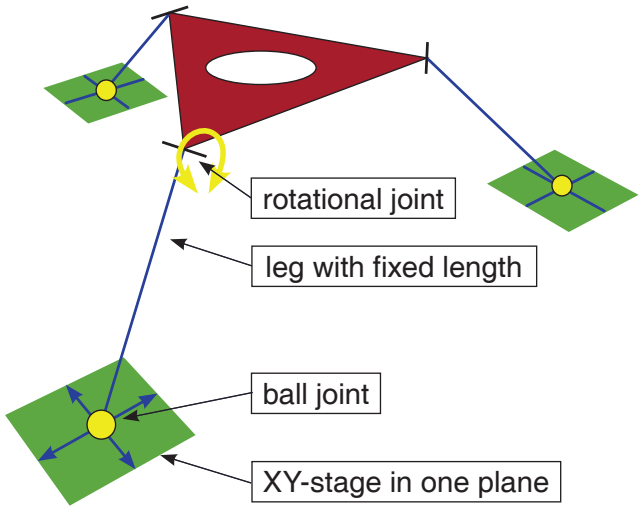
The InvenioSix is the world's only commercially available six-axis positioning mechanism with a fully closed-loop upper platform, provided as an optional feature. This feature makes the InvenioSix capable of high-resolution accuracy suitable for metrology.

Typical Applications

- Attach detector arrays to imaging system
- Steer and point laser beams, collimators etc.
- Align secondary mirrors in telescopes
- Auto alignment of optical components
- As a motion platform for six axis dimensional metrology and QA systems
- Micro-fabrication
- High-precision assembly tasks
- Optical tweezers manipulation
- Bio-genetic research

Principle of the InvenioSix Parallel Kinematics

The Parallel-kinematics architecture is the "cutting edge" of motion control and positioning technology today, and is completely differentiated from the traditional stacked-stages approach.



Mounted to the base plate inside the InvenioSix enclosure are three sets of XY linear actuators, each connected via a backlash-free precision strut to the moving top-plate, which carries the payload. Our proprietary non pre-loaded design can easily carry up to 1 kg of payload at a 150mm lever-arm without a reduction in performance, resolution or accuracy. InvenioSix provides a unique solution to modern parallel stage design.

InvenioSix has a sophisticated control system to perform real-time coordinate transformations. The controller generates a desired incremental move of the top plate by issuing a parallel real-time stream of commands to the six linear actuators using a dedicated DSP. This implementation allows for accurate contoured moves.

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Choose Coordinate System, Pivot & Path

Compared to three or 4-axis systems, a 6-axis mechanism is significantly more complicated. For example, the user is required to consider all of the following:

- Global (lab bench) coordinate system
- Local (tool-tip) coordinate system
- User-defined coordinate system (e.g. "XY" alignment plane tilted by 5 degrees)
- Polarity of each of the motion axes
- Pivot point location for each angular move
- Verifying the absolute location of the pivot point
- The specific path for any given move
- The absolute location of top plate relative to some well-defined reference
- Defining zones of the 6-axis work envelope where the stage is prohibited from going

Fortunately, InvenioSix-PC software manages all of these aspects in a clear, intelligent manner. In addition, it allows the user to define the pivot point at any location inside or even outside of the mechanism's motion envelope.

"Real-Time" Kinematics

InvenioSix software is equipped with highly complete, accurate and advanced forward and reverse kinematics model, which transforms the linear motions of the six motorized actuators into the desired linear and angular motion of the top-plate. As a result, all units are calibrated in mm / inches / degrees / radians and displayed in user-friendly relevant coordinates.

The InvenioSix software is written in a modular manner, i.e., using the dll and com structure making it very easy to interface our control library to Lab View or Visual Basic. It is also very easy to use GPIB for external instrument control.

We believe that the parallel-kinematics architecture out-performs traditional "stacked-stage" designs and offers significant improvements in the following areas:

Smaller size: With a 265mm x 290mm (10½" x 11½") footprint and a height[1] of just 175mm (7"), InvenioSix is smaller than a typical "stack". Also, the footprint to load carriying capacity ratio is smaller than any other "stack" or "parallel" mechanism with similar load capacity.

No moving cables or spring pre-loaded mechanisms: In the sub-micron realm, the non-linear forces exerted by moving cables actually disturb the alignment. We have eliminated pre-loading mechanisms from the moving platform.

Maximum speed by elimination of cantilevering: Long settling times are usually due to wobbling, cantilevered massed, which are commonplace in stacked-stages designs. InvenioSix effectively eliminates cantilevering altogether.

Excellent thermal stability: InvenioSix' fully enclosed mechanism quickly reaches thermal equilibrium and holds a position relative to the fixed center post for hours without thermally drifting.

Much higher load capacity: InvenioSix is equipped with sturdy struts and sophisticated flexure hinges designed to carry loads of 5kg; not compromised by the mounting orientation of the stage. This capacity is not possible with a comparably sized stacked-stage or parallel system.

More uniformly distributed load: With InvenioSix, the payload mass is evenly distributed across the six actuators. Compare this to stacked stages, where each lower stage must carry the weight of the ones above.

Lower moving mass: InvenioSix' intrinsically smaller mechanism (per kg of payload), more uniform load distribution, and parallel design, translate into a lower moving mass, which means faster step & settle time.

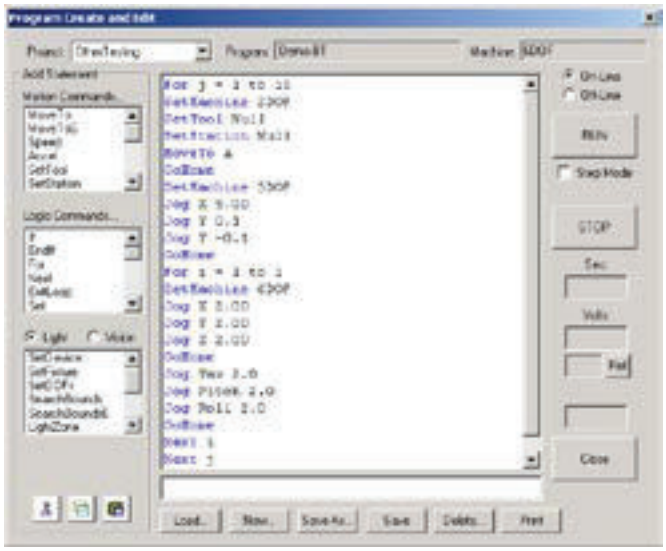
Simplified tuning: InvenioSix' parallel-kinematics design requires none of the painstaking adjustment and servo-tuning that is associated with that of a stacked-stage assembly.

More predictable, better-behaved motion: In a stacked stage assembly, each axis is controlled by an individual stage carrying a different load. Therefore, each axis has a different speed and dynamics property. In contrast, all of the InvenioSix actuators have the same characteristics, so the system's motion characteristics are much more uniform.

[1] With flat tool-flange and Z-value of 0mm.

InvenioSix PC Software

InvenioSix-PC controls the InvenioSix stage system. It is written in Microsoft C++ and runs on the Windows 2000 and XP operating systems. Its easy to use script language, with interpretive editor and code visual simulator, gives the user complete control over motion sequences, coordinate systems, and the location of the pivot point (i.e. axis of rotation)



A comprehensive software manual documents the high-level script commands.

Application examples

In the pictures below the InvenioSix is set up for alignment of optical components.

In both examples our customers were pleased with the precision of the mechanism, as well as the high-level integration of external devices into our software.

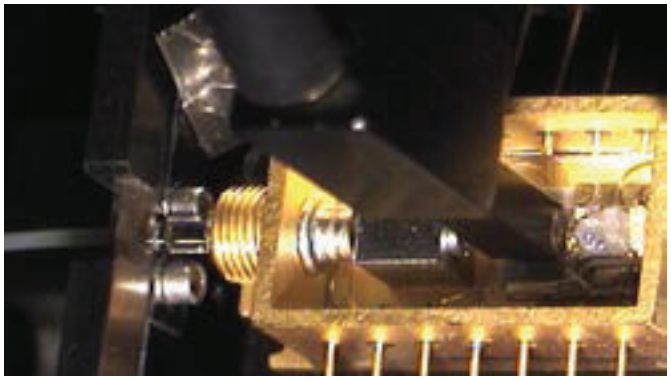


figure 1

InvenioSix System Components

- 6-DOF mechanism
- Cables
- Controller-amplifier unit (one - 19”rack)
- Pre-configured industrial PC
- InvenioSix PC software
- Canned motion & vision routines/algorithms
- PCI motion controller
- GPIB integrated software for communication with customer-supplied instruments

Options:

- Metric or English threads and hole patterns
- IEEE-1394 fire-wire vision cameras with lenses
- Camera mounting supports
- Angle bracket for mounting the InvenioSix mechanism at 90 degrees.
- Custom tool-flange and tooling for maximum flexibility
- Custom alignment routines and algorithms
- GPIB board for integrated communication with instrumentation
- Completely integrated fiber optics assembly platforms containing two InvenioSix systems, for fiber optic waveguide test & assembly
- Powerful LabView interface modules (VI’s) for quick and easy integration into LabView environments

Figure 1 is showing a multi-lens alignment in a laser-package. The customer is a manufacturer of optic-components.

Figure 2 shows the alignment of 3 LCD’s relative to each other through a quad-prism. The customer is a leading manufacturer of consumer-electronics.

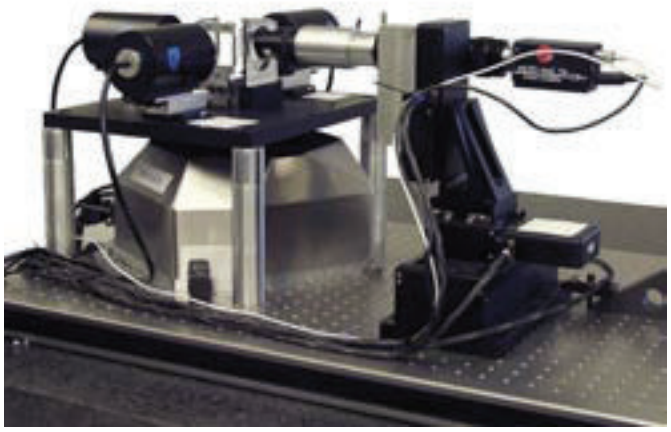


figure 2

Extended-Range InvenioSix Specifications:

Performance Parameter (measured at top-plate)	Value
Maximum linear (XY) range of motion	+/- 13mm
Maximum linear (Z) range of motion	+10 / -13mm
Minimum incremental linear (XY) move	33nm
Minimum incremental linear (Z) move	23nm
Linear (XY) accuracy, standard	± 2µm
Linear (Z) accuracy	± 15µm
Linear (XY) bi-directional repeatability	66nm
Linear (Z) bi-directional repeatability	46nm
Maximum linear (XY) speed	25mm/s
Maximum linear (Z) speed	17mm/s
Flatness/straightness of travel during linear (XYZ) moves	± 1µm
um angular range of motion[2]	+/- 8 for x and y+/- 4.5 for z
Minimum incremental angular move	0.235µrad
Angular accuracy	50µrad
Angular bi-directional repeatability (±3σ)	±0.29µrad
Maximum angular speed	10°/s
Load capacity (load centered on top plate)	4 kg
Cantilevered load capacity, load offset 150 mm (6 inches) from center of top plate	1 kg

Dimensional Parameter	Value
Footprint of mechanism (L x W)	265mm x 290mm
Height[3] of mechanism (H)	174mm
Weight of mechanism (base model)	11kg / (24lbs)
Length of cables between mechanism and controller-amplifier	2.4m
Dimensions of controller-amplifier (Industry-standard 19“ rack	482mm x 431mm x 3u 19“ x 17“ x 3u
Weight of controller-amplifier	25 lbs / 11.4kg
System line voltage	105-240 VAC 47 to 63 Hz
Analog input range	0-2V 12-bit 0-5V on request 0-10V on request
Maximum line current rating	5A
Standard operating Temperature: Humidity:	17 to 25°C (63 to 78°F) < 80 % RH
Storage environment Temperature: Humidity:	0 to 32°C (32 to 90°F) < 90 % RH
Impedance of analog inputs (for connecting power meters)	10 kΩ standard 50 kΩ on request

Unit conversions:

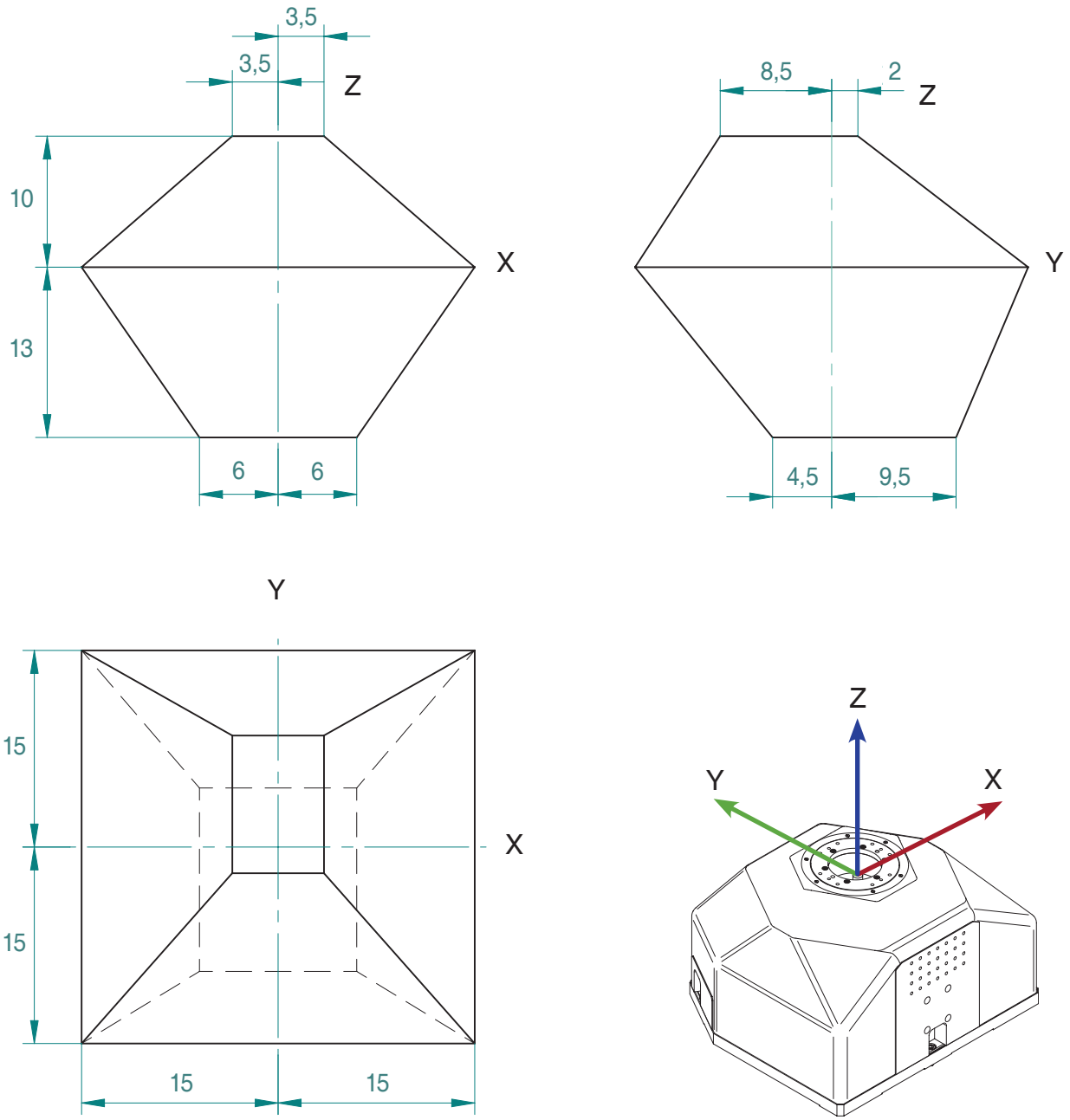
1 µrad	=	0.000 057 296°0.206
1 µrad	=	265 arc sec
1 µrad	≈	deflection of 1 µm / m
1 mm	=	0.039 370 08 inches
1 µm	=	0.000 039 37 inches
1 nm	=	0.000 000 039 37 in.

[2] Assumes no translation. The range will be reduced by the stage translation

[3] With flat tool-flange and Z-value of 0mm.

Workspace information:

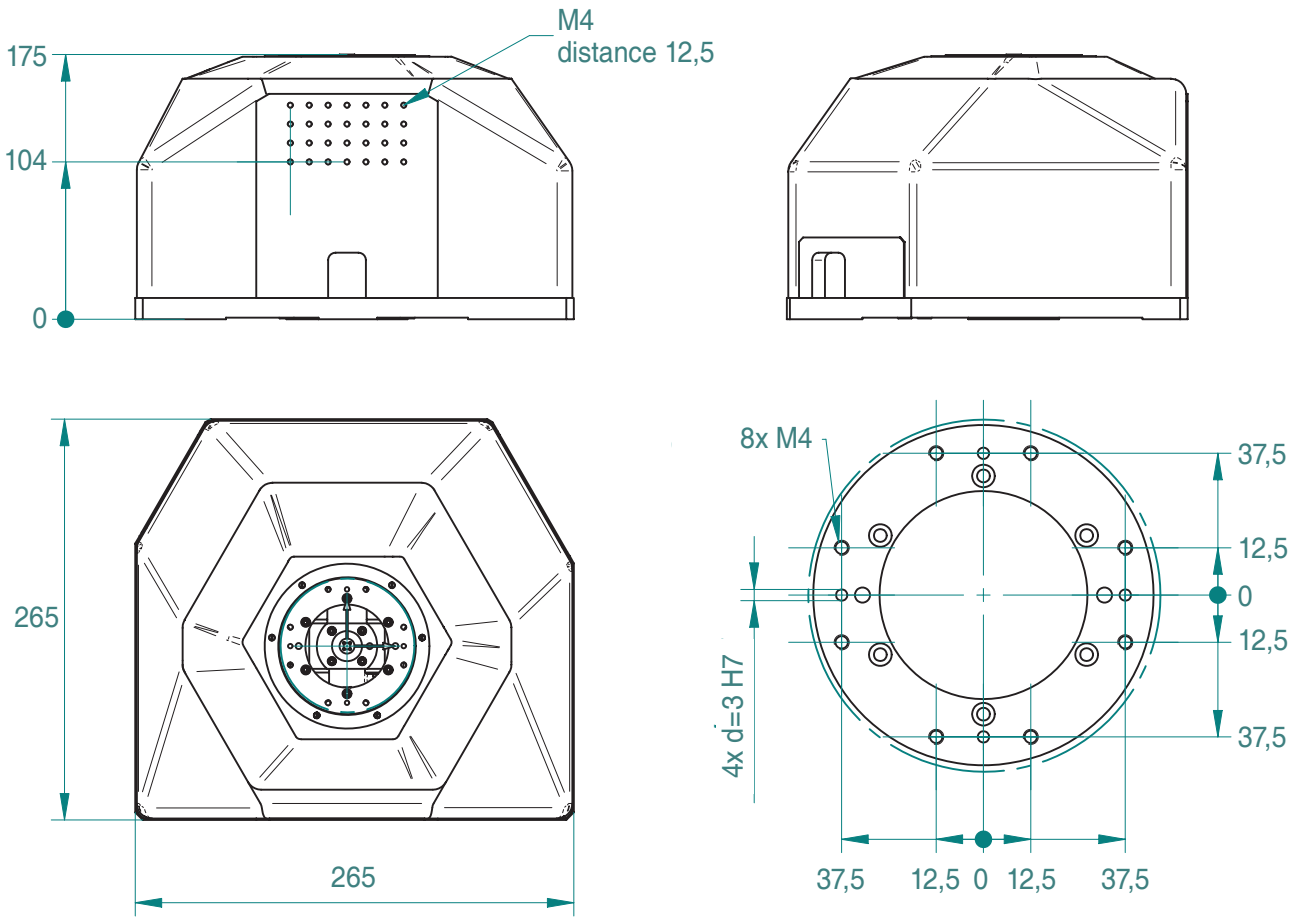
This graph displays the translational workspace[4]



All dimensions in mm

[4] The available angular range decreases towards the limits of the translational workspace

Dimensional information:



All dimensions in mm

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invenios

bonding your future

Invenios. Taking micromanufacturing to the third dimension.

Invenios is a manufacturer of precision linear and rotary stages, anthropomorphic platforms; turnkey, semi-auto-mated process solutions; and true 3D dynamic MEMS contract manufacturing; serving a broad range of tra-ditional and emerging micromanufacturing applications where “cost of packaging” is paramount.

For manufacturing syste integrators, Invenio-Stage™ and InvenioFlex™ positioning systems provide scalable platforms for the creation of high-speed, vision-guided measurement, alignment, and assembly systems with 10 nm precision.

For microsystem manufacturers in the photonics, disk drive, and the display arenas, turnkey semi-au-tomated tooling solutions - employing integral laser welding, soldering, and epoxy processes and state-of-the-art positioning systems built upon the Inve-nioSix™ and InvenioFlex™ technologies - deliver unprecedented production rates in the industry’s smallest foot print - all with nanoscale precision.

For microsystem product designers, Invenios offers a sub-micron, direct-write micromanufacturing pro-cess and quick-turn foundry/contract manufactur-ing services that together deliver true 3D dynamic MEMS structures on optical quality glass-ceramic substrates and high-aspect ratios with unprec-edented solution footprint advantages.

Invenios offers forward-looking manufacturers a complete array of products, process technologies, and services that have been designed to enable the next generation of low-cost packaging solutions for integrated nanosystem and microsystem products and technologies. At Invenios, we truly are taking micro-manufacturing to the third dimension.

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