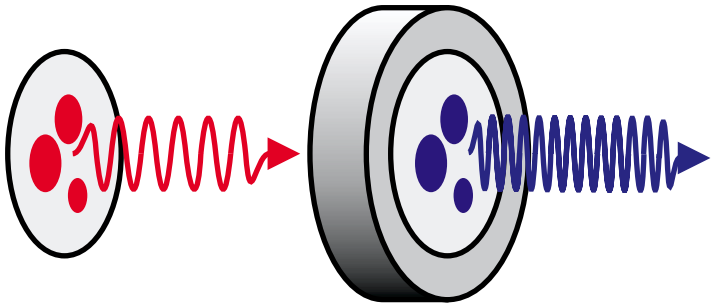
Ultra Fast Semiconductor-Gas Discharge Infrared Imagers



1.1 – 3.6 µm (Si:Zn)
1.1 – 10.6 µm (Si:In)
0.9 – 1.7 µm (GaAs:Cr)

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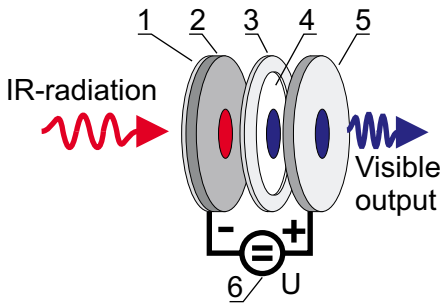
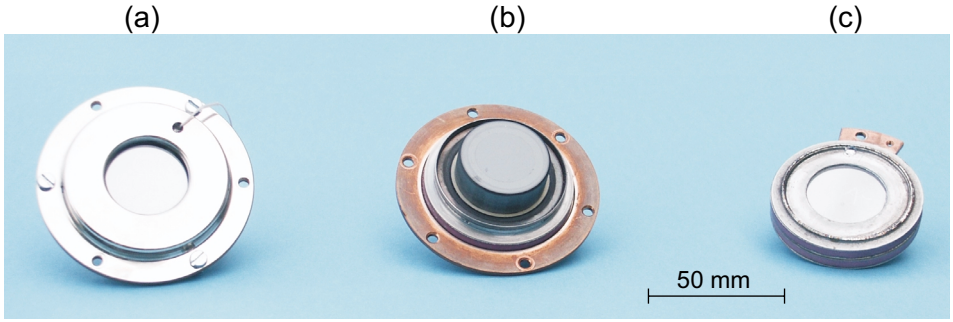
I. Principle of Operation & Cell Design



Schematic of the semiconducor-gas discharge infrared-to-visible converter:

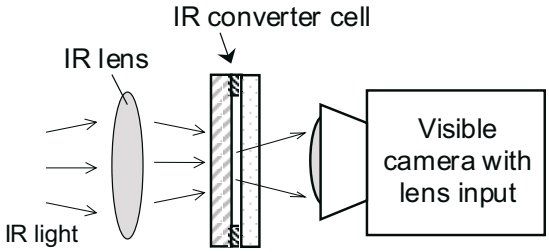
1 transparent cathode
2 photosensitive semiconductor
3 dielectric spacer
4 gas discharge gap
5 transparent anode
6 high voltage power supply

IR converter cell modules of different designs:
(a) shielded cell with a conventional output
(b) cell with a fiber optical output
(c) special lightweight cell for operation with a Stirling micro cooler

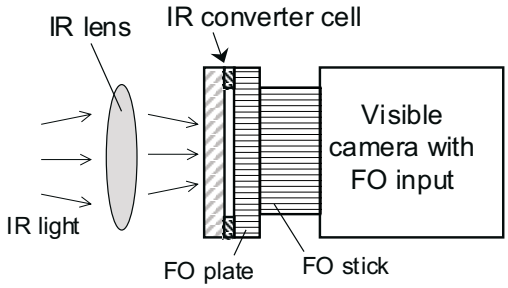


II. Integration with acquisition cameras...

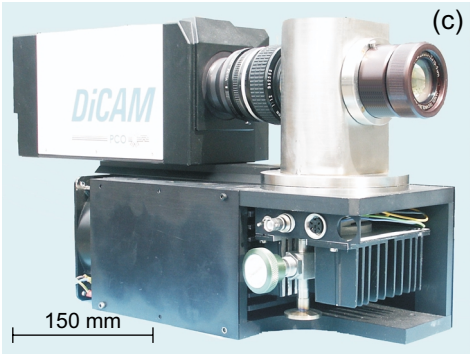
..by relay lens coupling

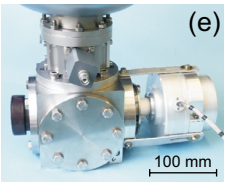


..by fiber optical (FO) coupling



III. Systems Implementation





(a), (b) Liquid nitrogen (LN_2) cryostats.

(c) IR imaging system utilizing a cooled converter cell chilled by a Stirling cooler (down to 77 K) and coupled with an ICCD camera by means of a relay lens.

(d) Near-IR camera based on an uncooled GaAs:Cr converter cell (black part) FO coupled to an ICCD-camera (silver part).

(e) IR imaging system on the basis of a LN_2-cooled converter cell FO coupled to an ICCD-camera.

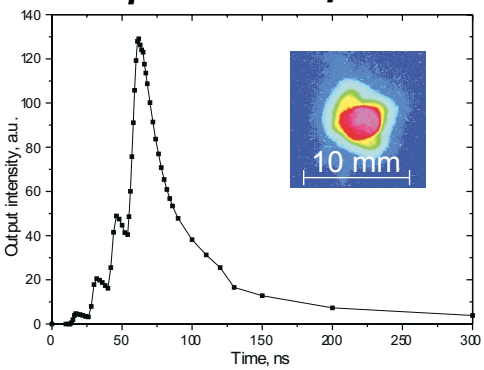
IV. Main Technical Parameters

Detector material		Si:Zn	Si:In	GaAs:Cr
Spectral range	µm	1.1 - 3.6	1.1 - 10.6	0.9 - 1.7
Wave length of max. sensitivity (λ_{max})	µm	2.3	7.1	0.9
Operation temperature	K	90	90	300
Response time	µs	1 - 10	0.05 - 0.1	0.5 - 5
Max. exposure time	ms	infinity	10	infinity
Active area	mm	27	27	20
Spatial resolution	lp/mm	7 - 13	5 - 8	7 - 13
Effective inscribed format	pix^2	500 x 500	300 x 300	360 x 360
Power conversion efficiency (W/W * 100 %)	%	5 - 15 (at λ_{max})	0.01 - 0.03 (at λ_{max})	0.6 - 2 % (at 1.4 µm)
Dynamic range	-	$>10^5$	>300	$>10^4$
Detectivity,	$cm\ Hz^{1/2}W^{-1}$	$(0.5 - 2) * 10^{11}$ (at λ_{max})	n.a.	n.a.

n.a. - not available

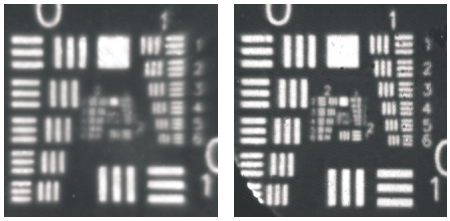
V. Selected Test Results on...

..Speed of response



Time response of a Si:In IR converter on a 100 ps laser pulse with a wavelength of $\lambda = 6.9$ µm.

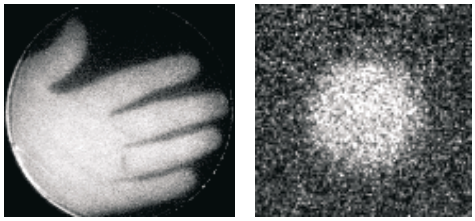
..Spatial resolution



a) b)

USAF test mask images taken by a Si:Zn IR converter.
(a) Conventional cell with a homogeneous gas layer. Resolution ~8 lp/mm.
(b) Improved cell with a micro-structured gas layer. Resolution ~13 lp/mm.

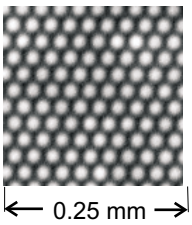
..Sensitivity



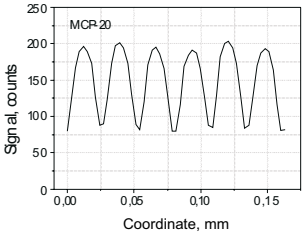
a) b)

Sample thermal images taken by Si:Zn IR imagers with different acquisition cameras (AC).
(a) Hand image (32-34 C). AC is a low-noise CCD with a F/1.4 lens. Exp. time 1 s, S/N = 20.
(b) 100 C black body image. AC is a FO coupled ICCD camera. Exposure time 1 µs, S/N = 3.

..Microstructuring the gas discharge layer



a)

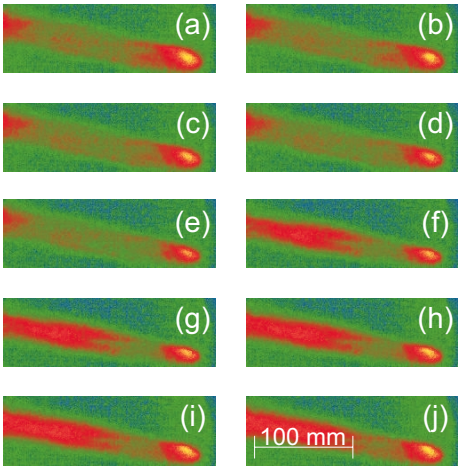


b)

Exemplary image (a) and glow brightness profile (b) of the gas discharge in the IR converter with a micro capillary plate (MCP). The diameter and the center-to-center distance of capillaries are 20 µm and 27 µm respectively. The modulation depth observed is ~40 %. The MCP-limited resolution is 18.5 lp/mm.

VI. Applications: High-Speed Thermography

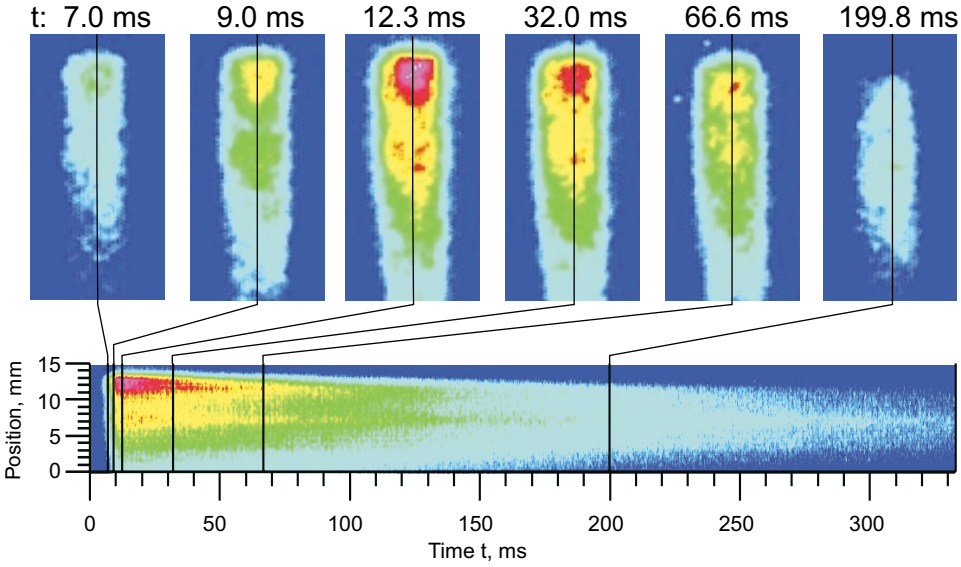
Laser beam welding



Series of thermal images of a laser beam welding process of stainless steel workpieces. The IR imaging system consists of a Si:Zn IR converter and a high speed CMOS camera running at a frame rate of 420 fps.

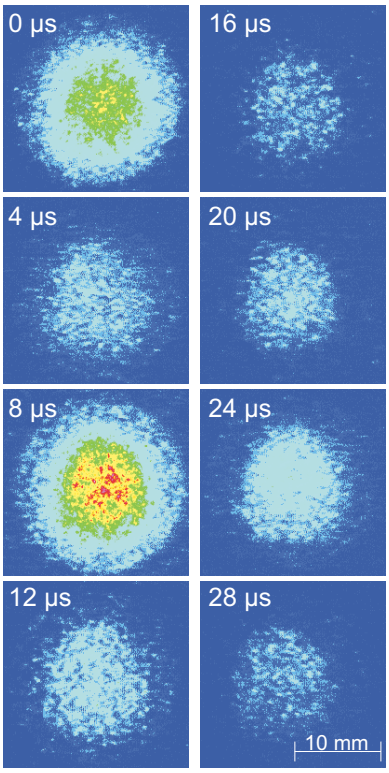
Heating and cooling down of a metalic foil

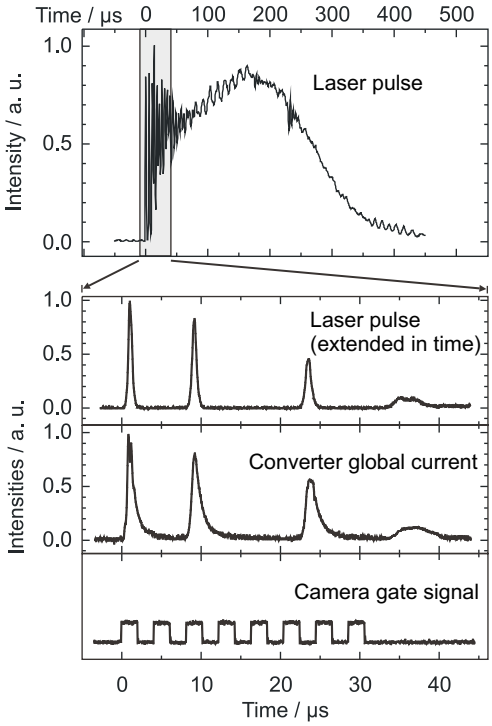
Selected frame thermal images (above row) and streak thermal image (below) of a metalic foil being heated by a current pulse and then cooled down freely. The IR imaging system consists of a Si:Zn IR converter and a high speed intensified CCD camera which has been run at a frame rate of 3000 fps and an exposure time of 1 µs.



VII. Applications: Time-Resolved Laser Beam Profiling...

..at a frame rate of 250 000 fps

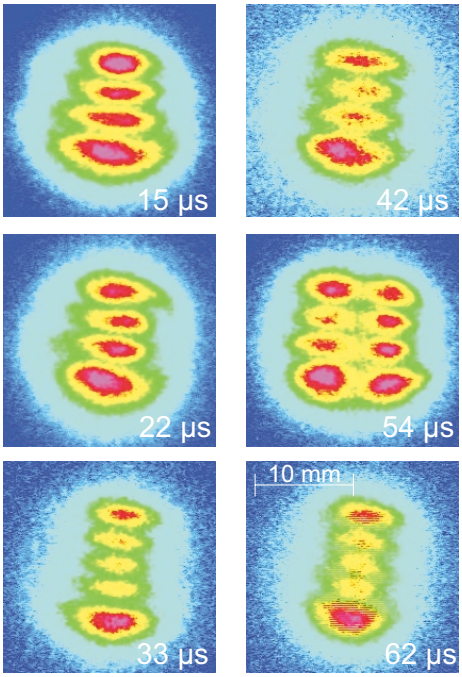




The laser is a 1.314 µm Nd:YAG. The IR imaging system comprises a Si:In IR converter and a framing streak camera (Hamamatsu C4187) operating at a frame rate of 250 000 fps and an exposure time of 2 µs. Time values in the pictures are delay times of the gating pulse.

..of a 2.94 µm laser (Er:YAG)

The IR imaging system consits of a Si:Zn IR converter and a gated intensified CCD camera. The exposure time is 10 µs. Time values in the pictures are delay times of the gating pulse. The laser pulse length is 250 µs.



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