“SECONDARY ARCING TRIGGERED BY HYPERVELOCITY IMPACTS ON SOLAR PANEL REAR SIDE CABLES WITH DEFECTS - COMPARISON WITH LASER IMPACTS”

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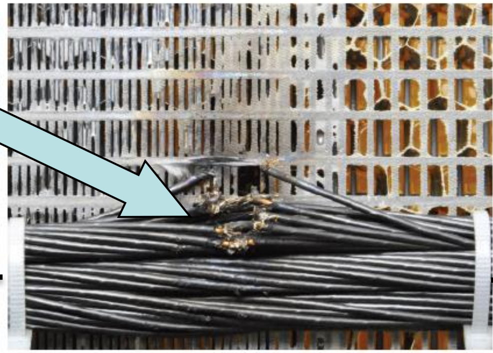
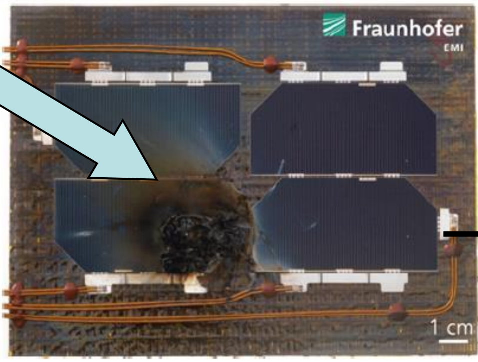
Outline

- Introduction
- Hypervelocity (HVI) and laser impacts plasma characterization
- Secondary arcing tests under HVI and laser impacts
- Summary

Background

Hypervelocity Impacts (Ø ≈1mm, a few km/s)





PSA

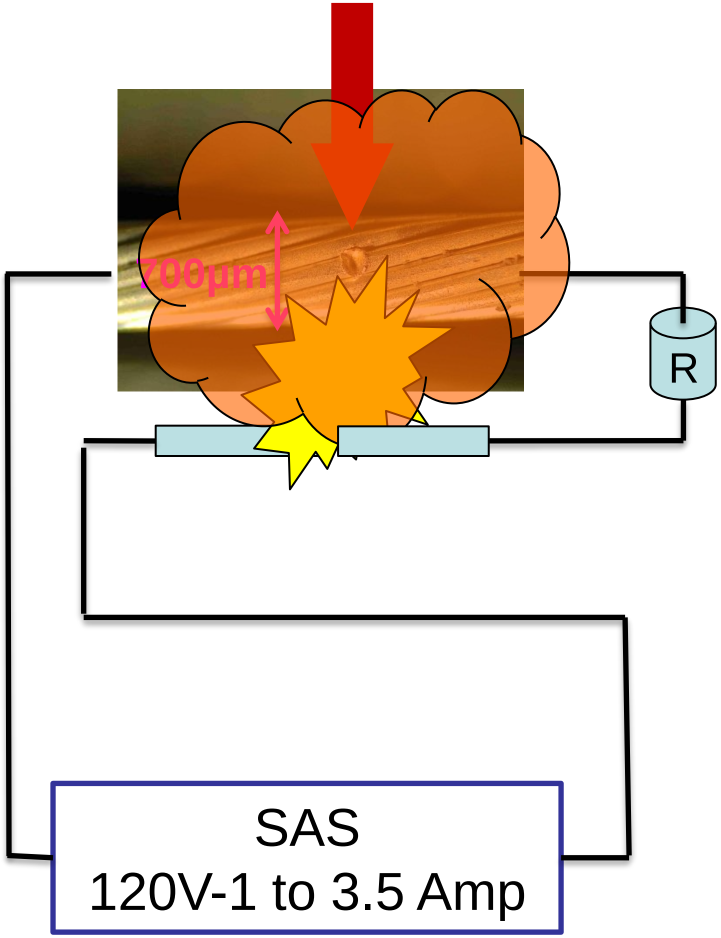
SAS
100V- few Amp

Probability ≈ 10^{-2} impacts/m^2/year

Objectives of this study:

Hypervelocity Impacts
(20µm<Ø <80µm, 20km/s>V>2km/s)

Probability ≈ a few 100 impacts/m^2/year

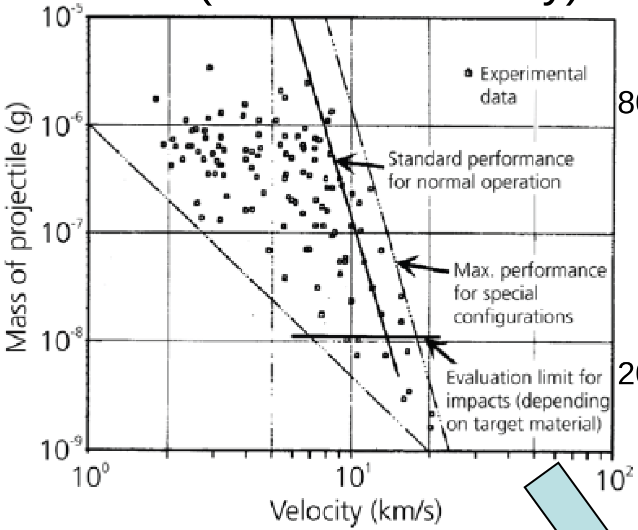


- What is the plasma produced by the impact ?
- Does this plasma trigger an arc ?
- Can we simulate the plasma of a HVI with a laser impact ?

- Mechanical effects are not considered in this study and defects are simulated

Plasma characterization with a triple probe

HVI (LRT-TUM facility):



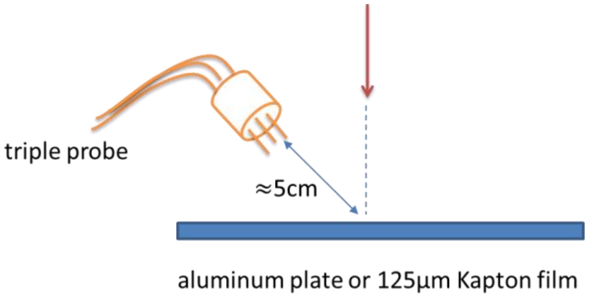
80µm

20µm

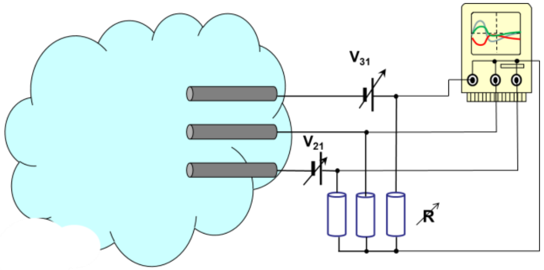
Projectile
(glass sphere)

Laser:

YAG 0.2J
1.06µm
20ns
Ø≈300µm

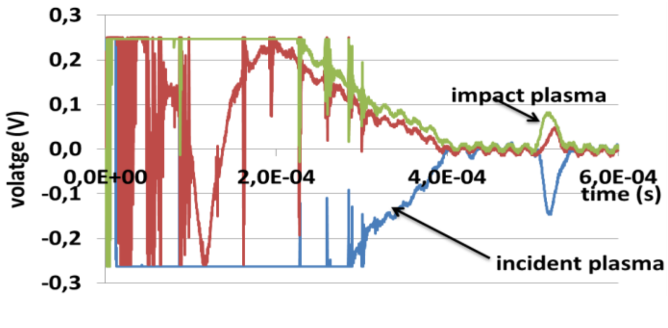


Triple probe:



impact plasmas characterization :

HVI:



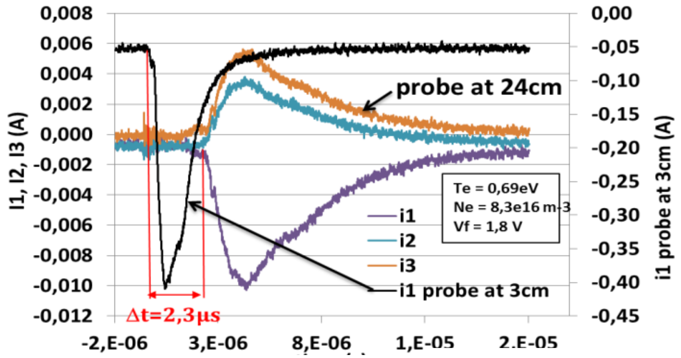
At ≈5cm:

HVI on aluminum	average	standard deviation
T_e	0.9 eV	0.2
N_e	$2.5.10^{14}$ m^{-3}	$1.1.10^{14}$ m^{-3}
V_f	2.8 V	0.7 V

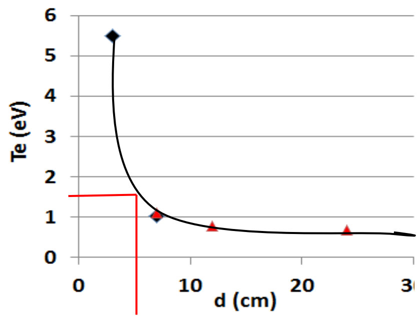
HVI on Kapton	average	standard deviation
T_e	0.9 eV	0.1 eV
N_e	3.10^{14} m^{-3}	$1.,3.10^{14}$ m^{-3}
V_f	2.7 V	0.2 V

Laser impacts:

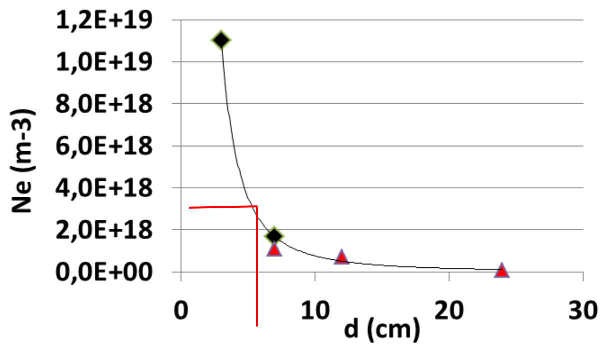
on aluminum:



➔Plasma velocity = 85±10km/s



5cm



5cm

At = 5cm:

Laser on Kapton (no perforating)	average	standard deviation
T_e	1.1 eV	0.2
N_e	$1.6.10^{16}$ m^{-3}	1.10^{16} m^{-3}
V_f	3.3 V	0.2 V

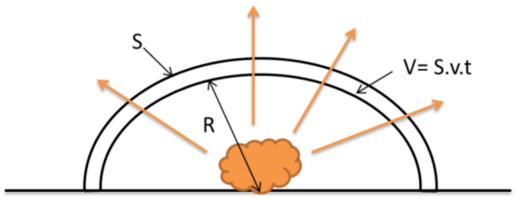
Comparison HVI and laser plasmas:

At ≈5cm:

aluminum :	HVI	Laser impacts
T_e	0,9 eV	2 eV
N_e	$2.5.10^{14}$ m^{-3}	$3.10^{18} m^{-3}$
V_f	2,8 V	7 V

Kapton 125 µm:	HVI	Laser impacts (no perforating)	Laser (perforating)
T_e	0.9 eV	1.1 eV	0.6 eV
N_e	3.10^{14} m^{-3}	$1.6.10^{16} m^{-3}$	$3.10^{15} m^{-3}$
V_f	2.7 V	3.3 V	1.6 V

Other differences to take into account:
- Directivity
- Escape velocity



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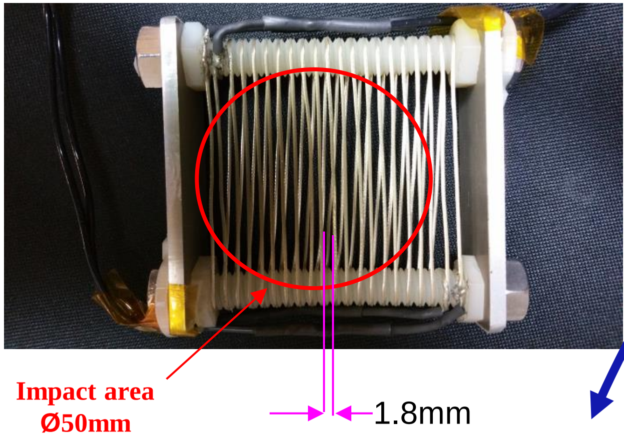
Integration:

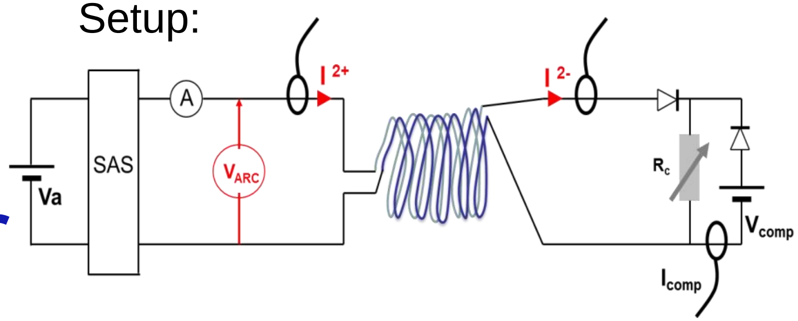
	Incident energy	Q calculated (Empirical models)	Q measured and integrated
HVI (Ø50µm/7km/s) on aluminum	0.4mJ< Q <25mJ	25nC<Q<140nC	9nC<Q<100nC
HVI (Ø50µm/7km/s) on Kapton	0.4mJ< Q <25mJ	5nC<Q<30nC	11nC<Q<120nC
Laser (0.2 J, 20 ns, $0.03mm^2$) on aluminum	200 mJ	110 µC	150 µC
Laser (0.2 J, 20 ns, $0.03mm^2$) on Kapton	200 mJ	50 µC	120 µC
ESD: 100pF *1kV	50 µJ	100 nC	
ESD: 150nF*1kV	75 mJ	150 µC	

Arcing with HVI plasma:

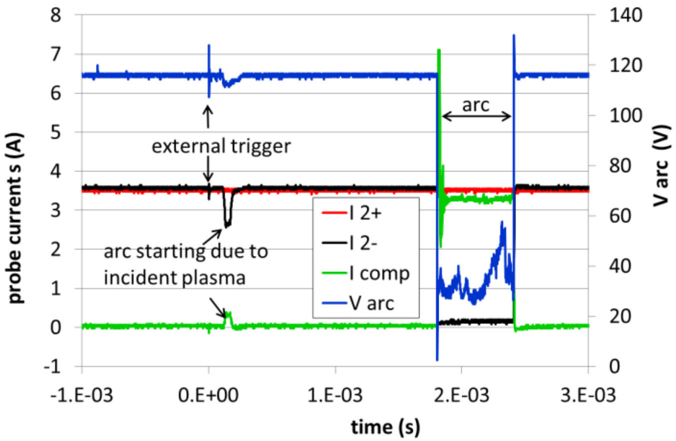
2 stripped solar array cables rolled up and interlaced:



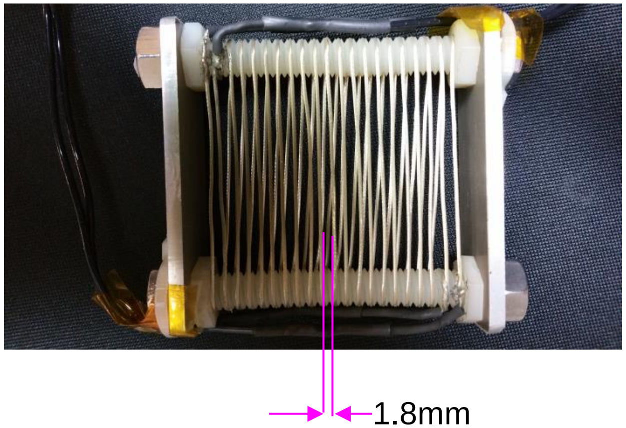
Setup:

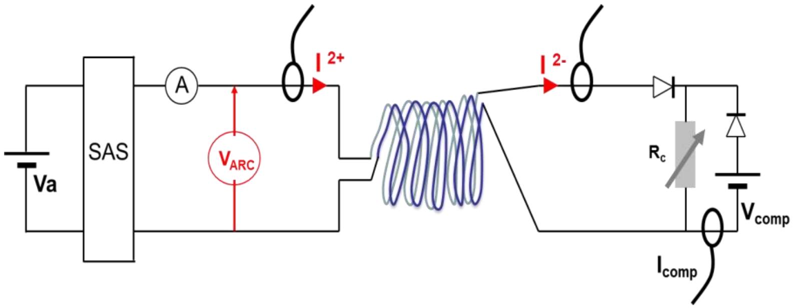


SAS values	Successful Shot #	Impact velocity (km/s)	Arc duration (µs)	V_{arc} (V)
120 V-1.2 A	2	4.5	800	?
	5	3.1	80	40
	13	7.8	500	55
	14	1.4	120	40
	15	8.8 et 5.7 (2 impacts)	40 and 60	30 and 40
	17	**8**	**1400**	**60**
	19	4.3	400	60
120 V-2 A	20	3	280	50
	22	6	80	70
	24	**3.8**	**2000**	**50**
120 V-3 A	32	5.4	720	45
	33	5.3	500	60
	36	5.6	600	50
120 V-3.5 A	37	4.8	400	30
	41	7.4	600	30



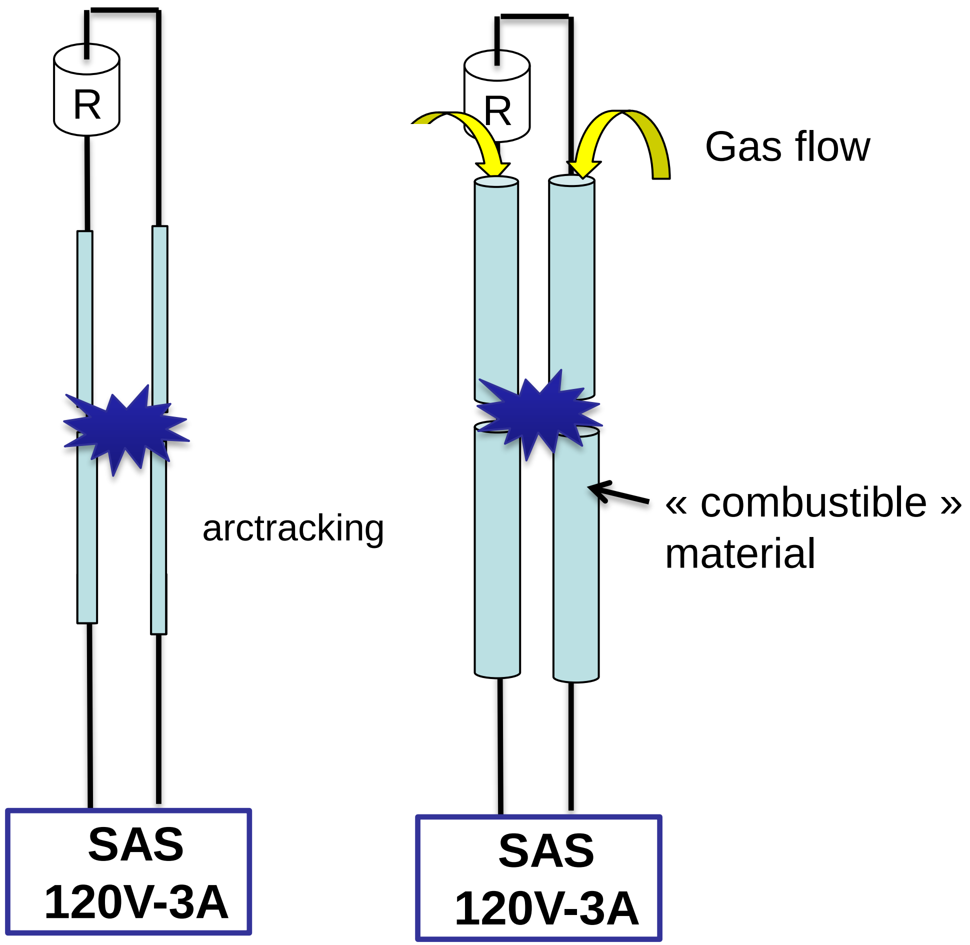
Arcing with laser plasma





SAS values	Succesfull shot #	Arc duration (µs)	V_{arc} (V)
120 V-1.2 A	1	50	55
	2	100	60
	3	180	60
	4	35	40
	5	60	30
	6	60	55
	7	100	55
	8	150	55
	9	70	50
	10	30	30
120 V-2 A	1	50	40
	2	150	55
	3	160	50
	4	80	60
	5	150	60
120 V-3 A	1	740	45
	2	1000	45
	3	1150	40
	4	850	50
	5	650	40
120 V-3.5 A	1	650	50
	2	650	50
	3	2900	25
	4	4700	25
	5	1800	25
	6	3200	25
	7	1900	25
	8	400	25

Why secondary arcs do not last longer….?



Summary

- We have characterized the plasma procuded by a hypervelocity impact and compared it with a laser impact plasma

- Even « small» HVI (above 20µm) trigger an arc between two cables separated by 1.8mm and 120V (voltage difference) :
  → considering the high probability of impact (a few 100 impacts/m2/year), the risk has to be considered seriously even for the front side solar array between 2 strings !

- With SAS=120V/1 to 3.5A → a few ms arcs : may last longer in space , up to PSA, because cables are not completely stripped but may be cracked or shrunk (due to aging, larger impact,…)

- For arc triggering studies, HVI impact plasma can be simulated with a laser impact providing that the laser is set to adequate (un)focalization and/or energy and there is no geometrical issue