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NOVEL PICKUP FOR BUNCH ARRIVAL TIME MONITOR

MOPC42

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ABSTRACT

For an optical-modulator-based BAM, a decisive parameter of the pickup output signal is the slope steepness. We suggest a novel pickup with flat thin electrodes in a transverse gap. Increasing the electrode width makes the steepness greater in proportion to the signal increase. For a given width, reducing the electrode thickness allows the ultimate steepness to be reached. Wave processes in the pickup were investigated on a large scale model, using the technique described in [1]. The DESY 40GHz button pickup was used as a reference. It was found that for the same overall dimensions the steepness of the flat electrode pickup can be increased by the factor of two. A way is shown to keep the steepness as high with transition to a more practical bandwidth 20GHz. The investigation results are the basis of a final pickup optimisation using electrodynamic simulation.

BUNCH ARRIVAL TIME MONITOR

In the electro-optical-modulator based BAM [2], the pickup output wave is sampled by a reference ultra-short laser pulse at the slope to distinguish whether the bunch passes earlier or later than the reference pulse.

The slope steepness is a decisive parameter that defines modulator/BAM sensitivity and resolution.

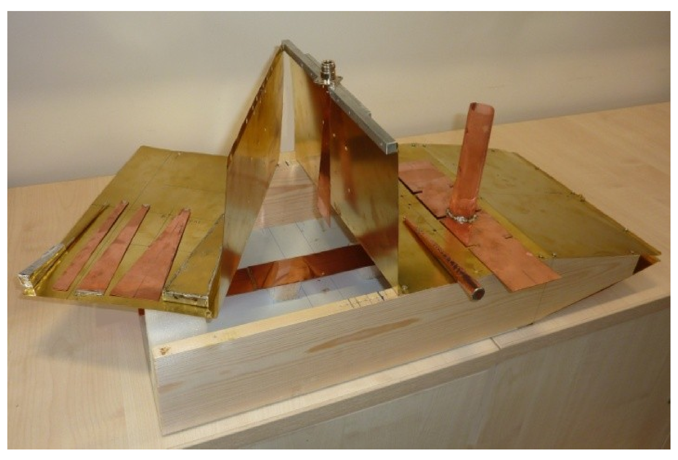
For button pickup an ultimate steepness limit is present because of the pickup circular geometry.

We attempted to break the limit above. We suggest decoupling the pickup two key parameters, width and length, by using a flat thin electrode.

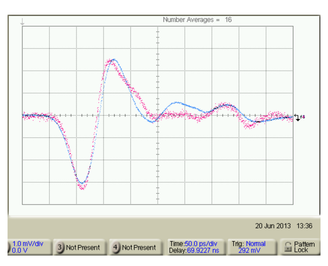
We investigated on a model both this novel electrode and the cone-shaped button electrode [3].

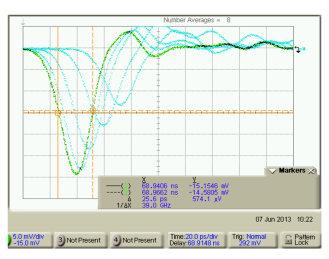
PICKUP LARGE SCALE MODEL AND MEASUREMENT TECHNIQUE [1]

Bunch length 5.4mm. It is to be << than electrode/gap size. It lays down a model scale >5:1 as regards to a BAM pickup in [3]. Electrode size range 10mm to 50mm. Gap length range 5mm to 25mm. Linear arrangement.



- 20GHz (17ps) oscilloscope
- **Output signal** was measured **directly**
- **Wave electric field** was measured **with capacitive probe**





The probe output is proportional to **derivative.** We **integrated** not the output but **the beam.** For probe the beam was a step (12ps), for electrode output the beam was a pulse (18ps) obtained with a differentiator. In the plot above: the electrode output with pulse is blue, the same signal with step and probe is red.

The beam TEM line effects:

- ❑ A wave of a strip placed between two conductive planes decays with distance from the strip. **For a broad electrode this effect reduces effective pulse magnitude.**
- ❑ Constant phase surface is not a plane but a convex centred at the transition coax-circular to coax-flat. **For a broad electrode this effect increases effective bunch length.**

ONE-GAP ELECTRODE [1]

➢**First, we investigated an elementary electrode structure: one-gap transverse flat thin electrode.**
Two gaps, on each side. One only gap interrupts the wall current induced by beam (active gap). Another one is short-circuited (passive gap).

A BAM pickup is the superposition of two one-gap structures.

➢**The waves excited in a one-gap electrode structure were measured at either gap** at four points: at 1cm, 5.5cm, 10cm, and 14.5cm distance from the electrode edge. To identify the waves, **the electrode end was made short, open, and connected to a output coax connector pin.**

➢The electrode width was 30mm tapered down to 10mm at the connection point. Each gap length was 15mm tapered down to 5mm at the end.

➢The investigation results:

1. The waves propagated as **TE-like compact packets** guided by the electrode.
2. The packet length was about **gap length over c.**
3. Some **residue coupling** of the passive gap and beam took place.
4. At the connection point the active gap **principally can't be matched.**
5. **Multiple reflections** produce output packets spaced by double electrode length over c.

At the connection point, **four lines** are interconnected: an active gap excited by beam, a passive gap, with its own impedance, an output 50Ohm coax line, and one more, internal coax line with the electrode as a central wire.

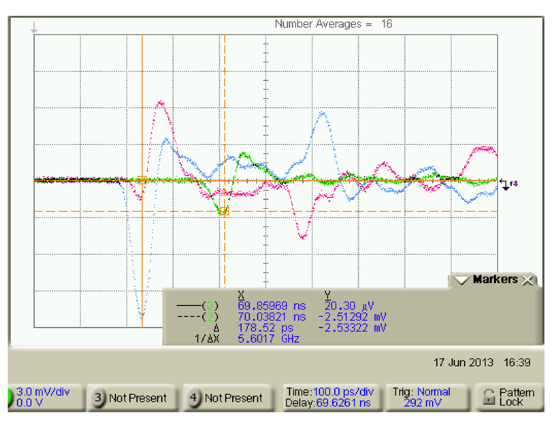
TE-like wave packet **converts** to TEM-output at the connection point. We didn't try to find **an optimal trade-off of the impedances** to get **the output maximised.** This can be better done using a simulation package.

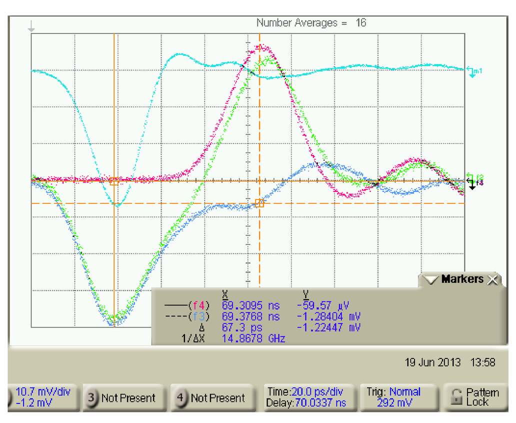
BAM PICKUP AS TWO-GAP PICKUP

❑**Two-gap electrode has each gap open and active.**

❑**The rear gap is excited by beam later than the front gap. For a thin electrode the delay is minimal and equal to gap over c.**

❑Packet propagation and reflection occur analogously to one-gap electrode. Output signal is green (divided by 2). Packets in the front/rear gap taken at 1/3 from the connection point are blue/red.





1. The incident packets are spaced by **gap length over c.**
2. **Reflected and passed packets** are seen on the right from the grid central line. They are spaced by gap length over c and go in the gaps in **reverse** orders.
3. One more effect is seen: **spreading of the incident packet around the electrode** into the opposite gap.

❖The output signal as **a superposition of two packets** is shown on the right as green. The bunch is blue.
❖The output signal is **asymmetrical** due to spreading of the front gap incident packet around the electrode.
❖**The asymmetry of a cone-shaped button electrode** has similar origin. As for this pickup the spreading occurs significantly **earlier,** reflected packets are **adjacent** to the incident packets. The superposition of them makes the output asymmetrical in magnitude/shape. See **simulation plots in [3].**

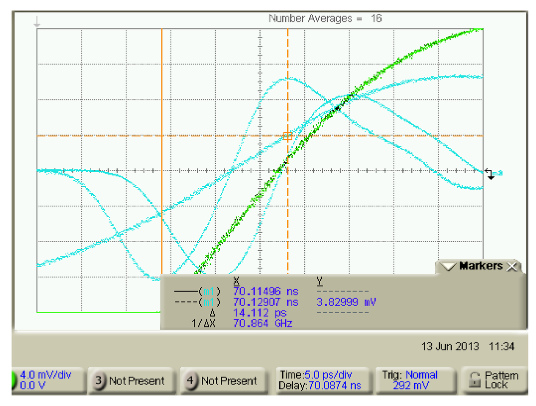
SLOPE STEEPNESS

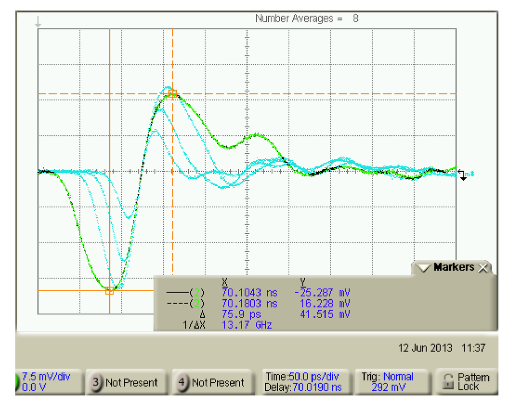
➢We **compared slope steepness** of **the flat electrode** to that of **the cone-shaped button electrode.** The flat electrode had the gaps 15mm to match the wave half-period to that of the button electrode. Both the electrodes had the TEM impedance close to 50Ohm.

➢Wave electric field was measured with capacitive probe

➢The button electrode had diameter 14mm in an enclosure of diameter 28mm. The flat electrode had width 30mm.

➢In the plot, the left wave is the button signal, the next wave is the flat electrode signal. A zoom of both has 5ps/div and 4mV/div.





➢**The flat electrode steepness is 1.35, the button electrode steepness is 0.71, the ratio is 1.9.**

➢**The flat electrode advantage is factor of 2 in steepness.**

➢Width=constant (30mm). **Dependence on gap length.**

gap length, mm	5	8.5	15	25
half-period, ps	33	44	60	76
magnitude, mV	18	32	42	41
steepness, a.u.	0.99	1.33	1.37	1.20

Left column: effective gap length

➢Gap length=constant (15mm). **Dependence on width.**

electrode width, mm	17	30	51
half-period, ps	62	60	59
magnitude, mV	36	42	49
Steepness, a.u.	1.18	1.37	1.56

Left column: effective gap length. Right column: beam TEM line effects.

➢**Steepness for width / gap ratio=constant (=2).**

electrode width, mm	17	30	51
gap length, mm	8.5	15	25
half-period, ps	47	60	76
steepness, a.u.	1.11	1.37	1.20

Left column: scope rise time. Right column: beam TEM line effects.

SUMMARY

We attempted a model-based investigation of wave excitation and propagation in pickup electrode structures up to the times of the order of gap length over c. A short pulse in a TEM line was used as a beam. We developed a capacitive-probe-based technique for wave electric field measurements.

We investigated an elementary electrode structure that is a one-gap transverse flat thin electrode, a two-gap electrode as a BAM pickup, and a cone-shaped button pickup of [3]. It was found that a flat electrode pickup has the slope steepness twice that of the button pickup. We investigated some effects in these two BAM pickups and tried to interpret them.

The obtained results are the basis for a final pickup optimisation. They can be used as a guide for electrodynamic simulation. From other side, the simulation would provide with verification/specification that some results need.

REFERENCES

[1] A. Kalinin, "Pickup Electrode Electrodynamics Investigation", WEPC26, these proceedings.

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[3] A. Penirschke at al., "RF Front End for High Bandwidth Bunch Arrival Time Monitors in Free-Electron Lasers at DESY", IBIC 2012.

[4] J. A. Clarke at al., CLARA Conceptual Design Report, STFC Daresbury Laboratory, 2013.