

Lightning Physics and Effects

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Leader/Return Stroke versus M-Component Mode of Charge Transfer to Ground in Initial-Stage Pulses of Upward Lightning

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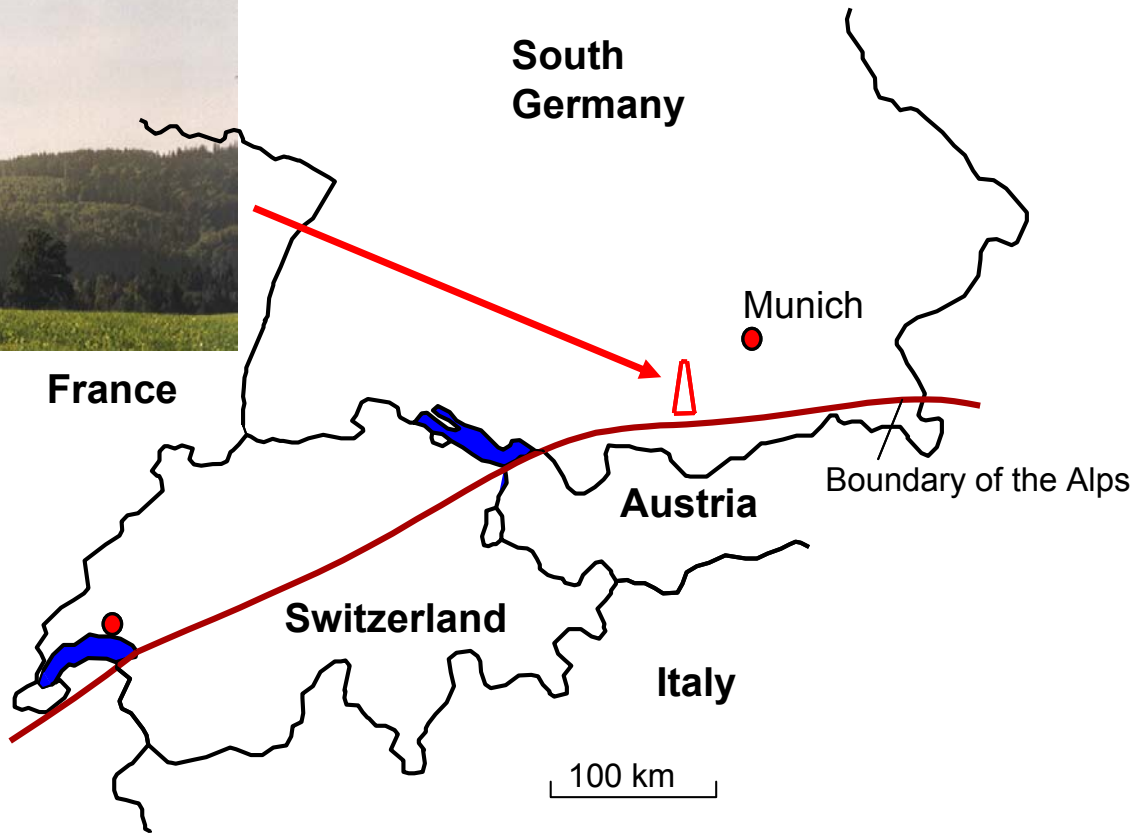
Peissenberg - Station



- Current measurement
 - at the tower top (160 m)
- Measuring cabin
 - about 200 m from the tower
 - fast speed camera (1000 frames/s)



Location of the Peissenberg tower

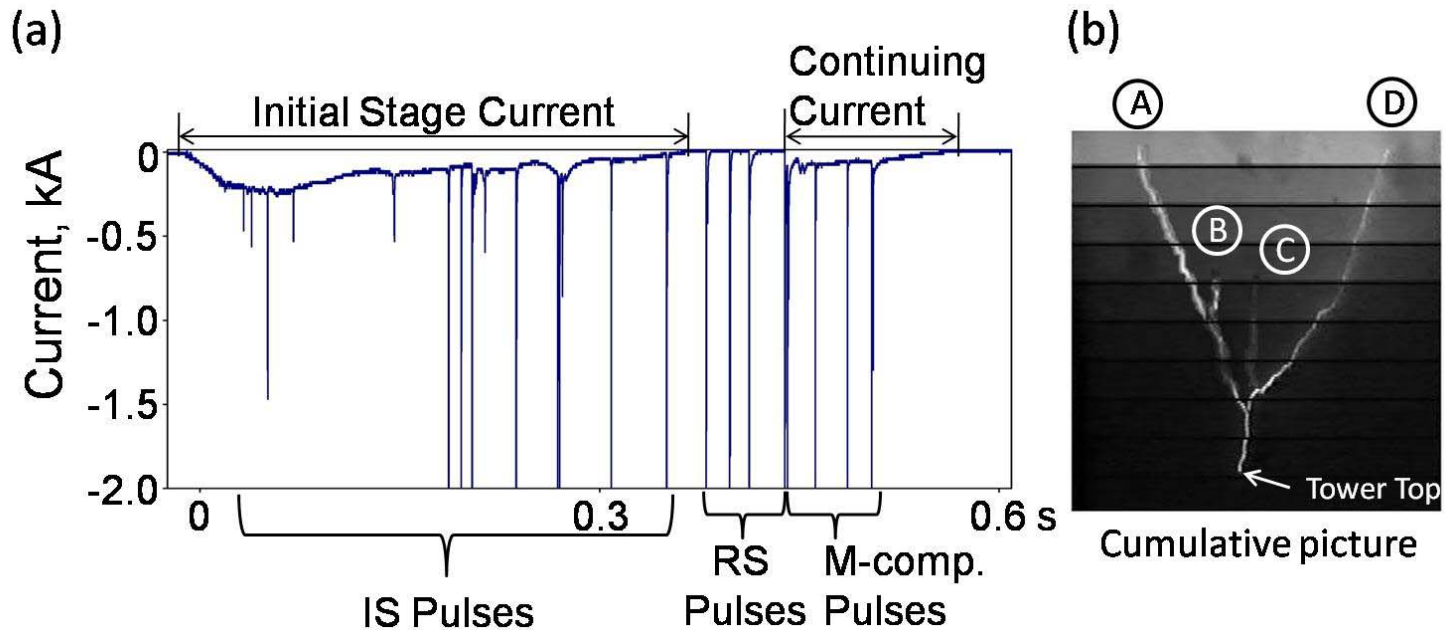


Current record and video image

(a) Low-current record

- initial-stage (IS) current with superimposed IS pulses
- 4 return-stroke (RS) pulses
- 4th return-stroke followed by continuing current with 5 superimposed M-component pulses

(b) Cumulative video image of the same flash



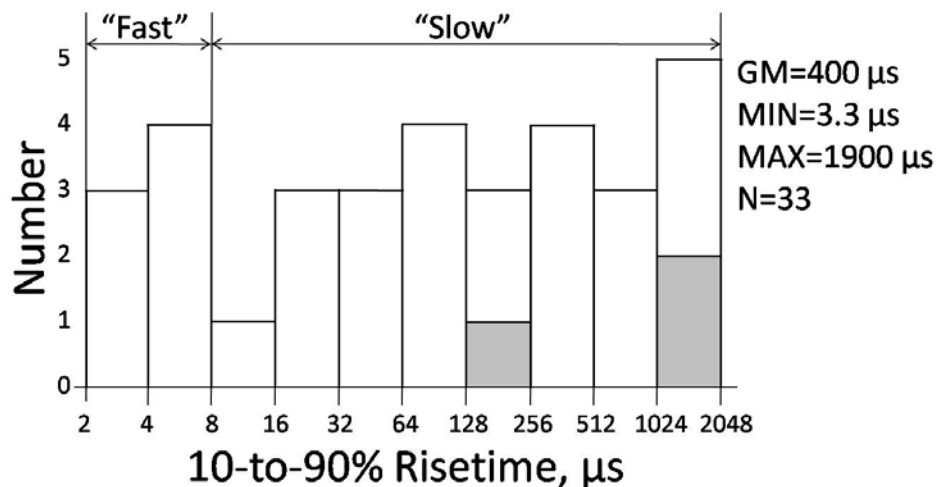
Summary of eight flashes analyzed in this study

Flash ID	Date	Polarity	Number of IS pulses	Number of return stroke pulses	Number of M-component pulses	Total number of pulses
1	28 March 1997	+	3	none	none	3
2	28 March 1997	-	5	none	none	5
3	29 March 1997	-	5	none	none	5
4	06 January 1998	-	14	4	5	23
5	05 March 1998	-	3	none	none	3
6	08 March 1998	-	1	none	none	1
7	29 April 1998	+	none	1	4	5
8	17 February 1999	-	2	none	none	2
Total			33	5	9	47

IS current pulses

(Data for positive lightning are shaded)

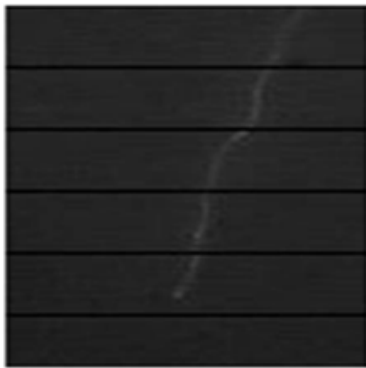
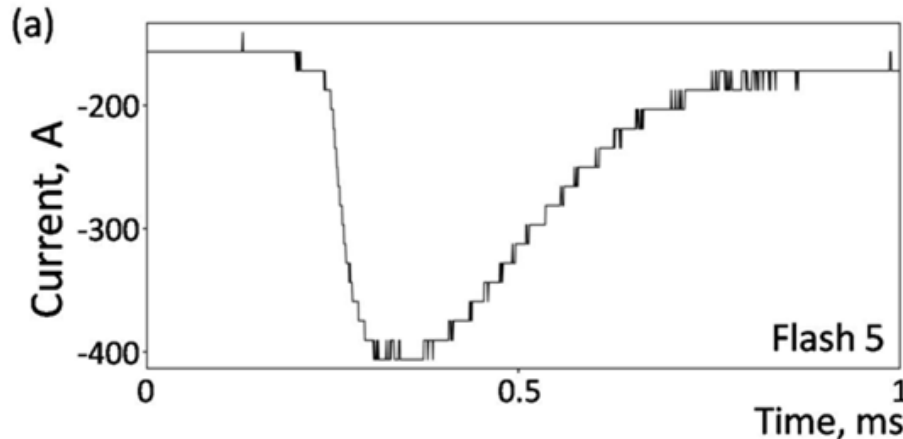
- 10-to-90% risetimes: 3.3 μs – 1900 μs , GM: 400 μs
- Superposition of two distributions with the borderline at about 8 μs
 - “Fast” pulse: risetime shorter 8 μs
 - “Slow” pulse: risetime longer than 8 μs
- Only the negative lightning had fast impulses, all observed 3 IS-pulses of positive lightning were slow
- 7 fast pulses: 3.6 kA – 13 kA (GM: 6.5 kA)
- 26 slow pulses: 156 A – 6.2 kA (GM: 1 kA)



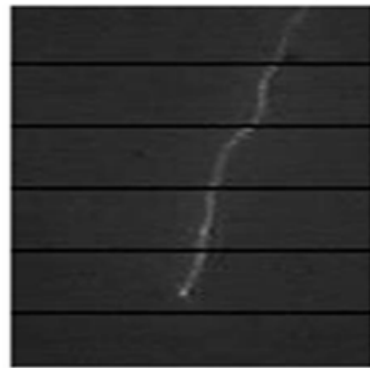
M-components

- 9 M-components
 - 5 M-components from negative lightning
 - 4 M-components from positive lightning
 - 10-to-90% risetimes: 3 μs – 1775 μs , (GM: 277 μs)
- Superposition of two distributions:
 - 4 M-components (all from negative flashes) belonged to the “fast” category (10-to-90% risetimes shorter than 8 μs)
 - 5 M-components (4 from positive flash) belonged to the “slow” category
 - There were no M-component with risetimes between 8 μs and 32 μs
- “Fast” M-components: 3 kA – 11 kA (GM: 6.6 kA)
- “Slow” M-components: 156 A – 1.2 kA (GM: 480 A)

Video images: „Slow“ category



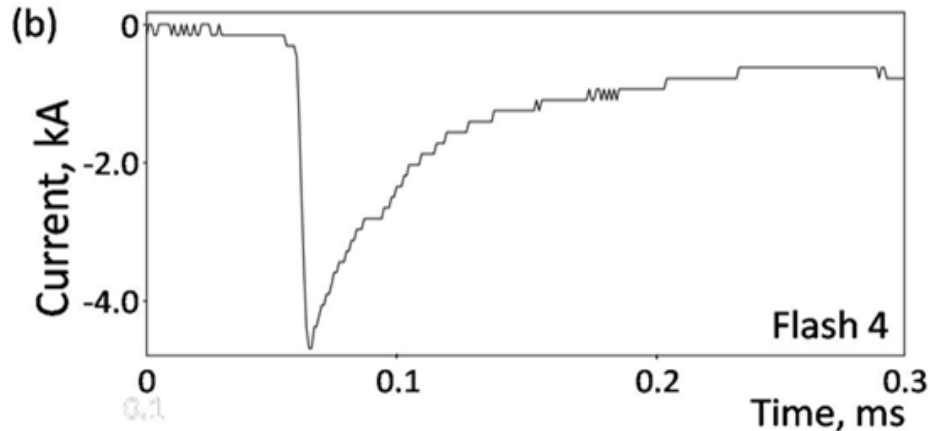
Background IS current



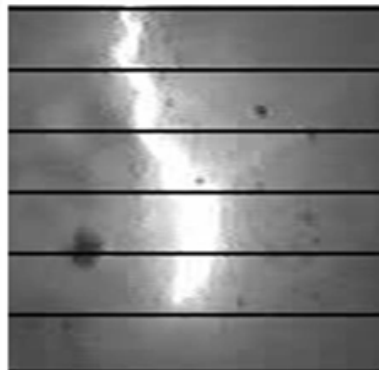
Pulse superimposed
on IS current

- „Slow“ IS-current pulses
 - development in the same branch as the background IS current
 - 25 or 96% of 26 “slow” IS-pulses showed that behavior
- „Slow“ M-components
 - development in the same branch as the background continuing current
 - All 5 (100 %) „slow“ M-components showed that behavior

Video images: „fast“ category



Background IS current
(brightness inverted)



Pulse superimposed
on IS current

- „Fast“ IS-current pulses
 - development in a different branch compared to the background IS current
 - 6 or 86% of the 7 “fast” IS-pulses showed that behavior
- „Fast“ M-components
 - development in a different branch compared to the background continuing current
 - All 4 (100 %) „fast“ M-components showed that behavior

Summary

- From our analysis of 33 IS current pulses and their correlated video images, we found that seven IS pulses had shorter ($< 8 \mu\text{s}$) 10-to-90% risetimes, six (86%) of which developed in a branch, which carried an insignificant, if at all, current immediately prior to the pulse occurrence.
- A similar trend was found for nine M-component pulses. Four M-component pulses with 10-to-90% risetimes in the range of 3 to 6 μs each developed in a newly-illuminated branch.
- Thus, both IS and M-component pulses with shorter ($< 8 \mu\text{s}$) risetimes tended to use branches that did not carry appreciable current immediately prior to the pulse occurrence. In our interpretation, these events represent the leader/return stroke mode of charge transfer to ground.

Summary

- On the other hand, 25 (96%) of 26 IS and all five M-component pulses with longer ($> 8 \mu\text{s}$) risetimes occurred in already luminous channels. These, in our interpretation, are manifestations of the M-component mode of charge transfer to ground.
- Although, there was one exception in each category, overall results do support the hypothesis that longer risetimes are indicative of the M-component mode of charge transfer to ground, while shorter risetimes are associated with the leader/return stroke mode.