Get Your Hands Off My Laptop: Physical Side-Channel Key-Extraction Attacks on PCs

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Side channel attacks

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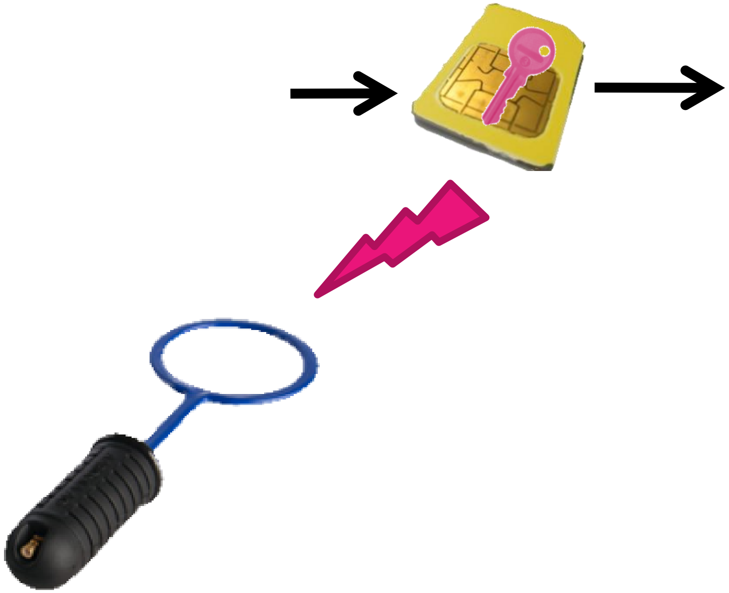

electromagnetic

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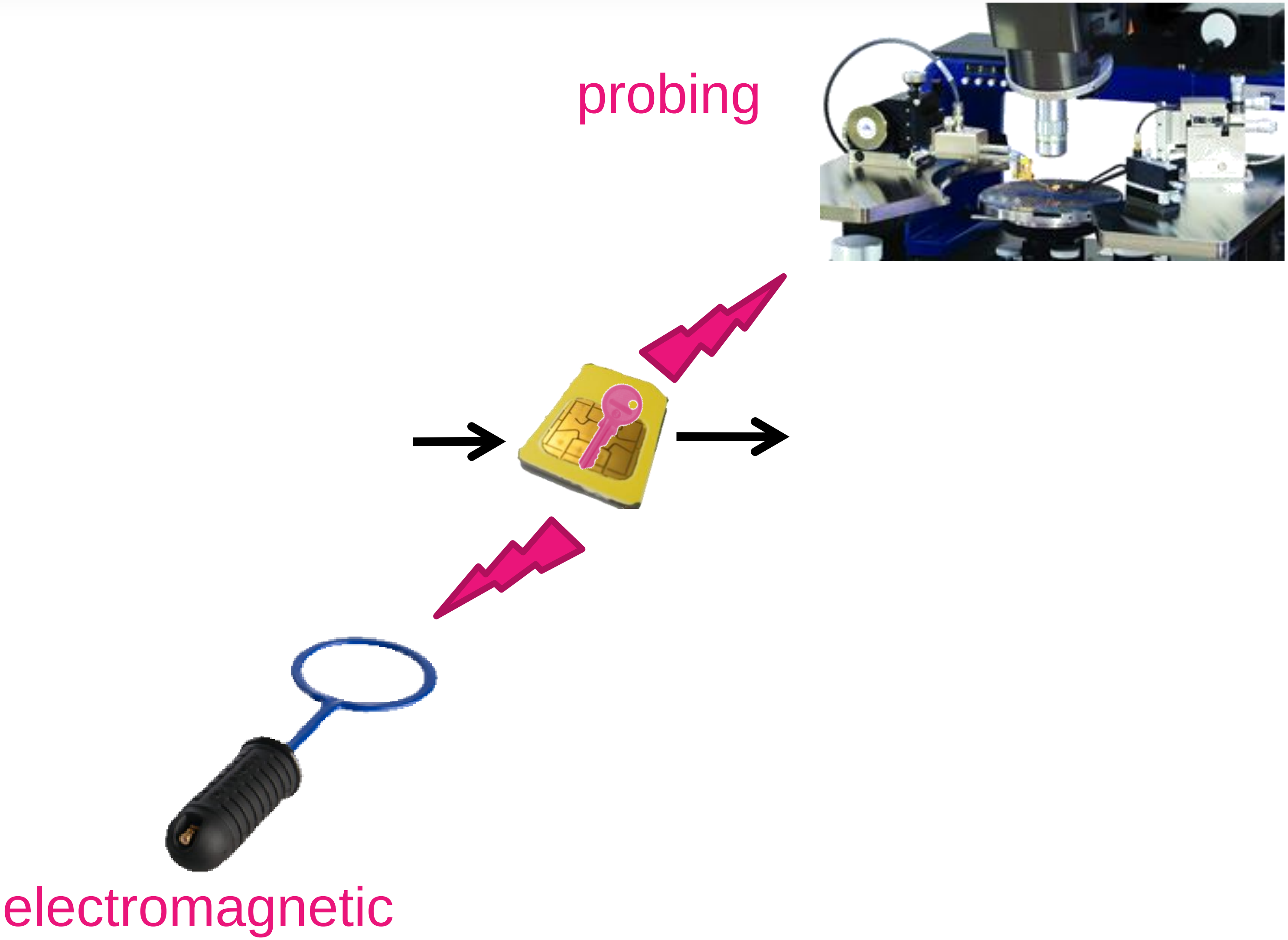

probing

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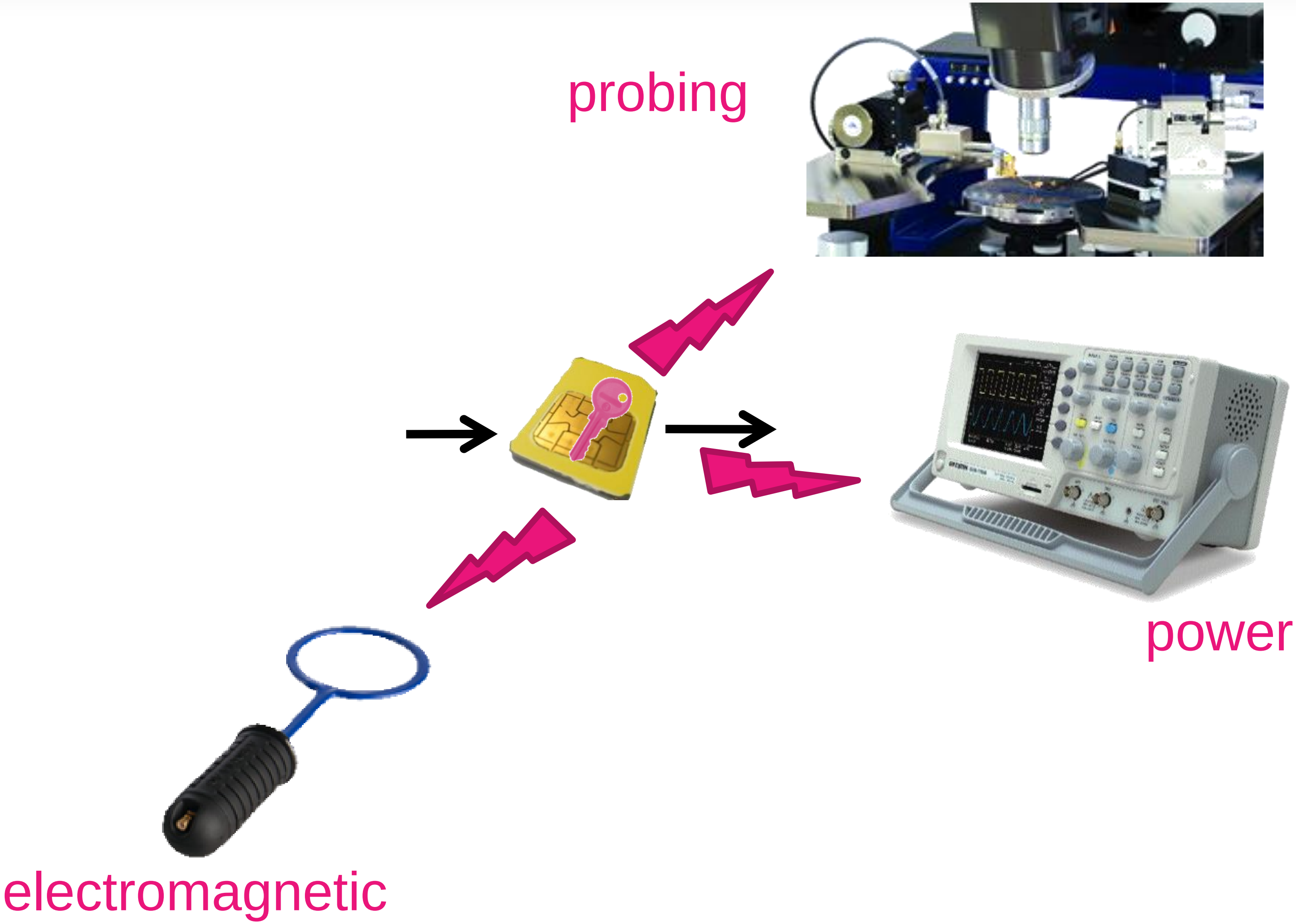

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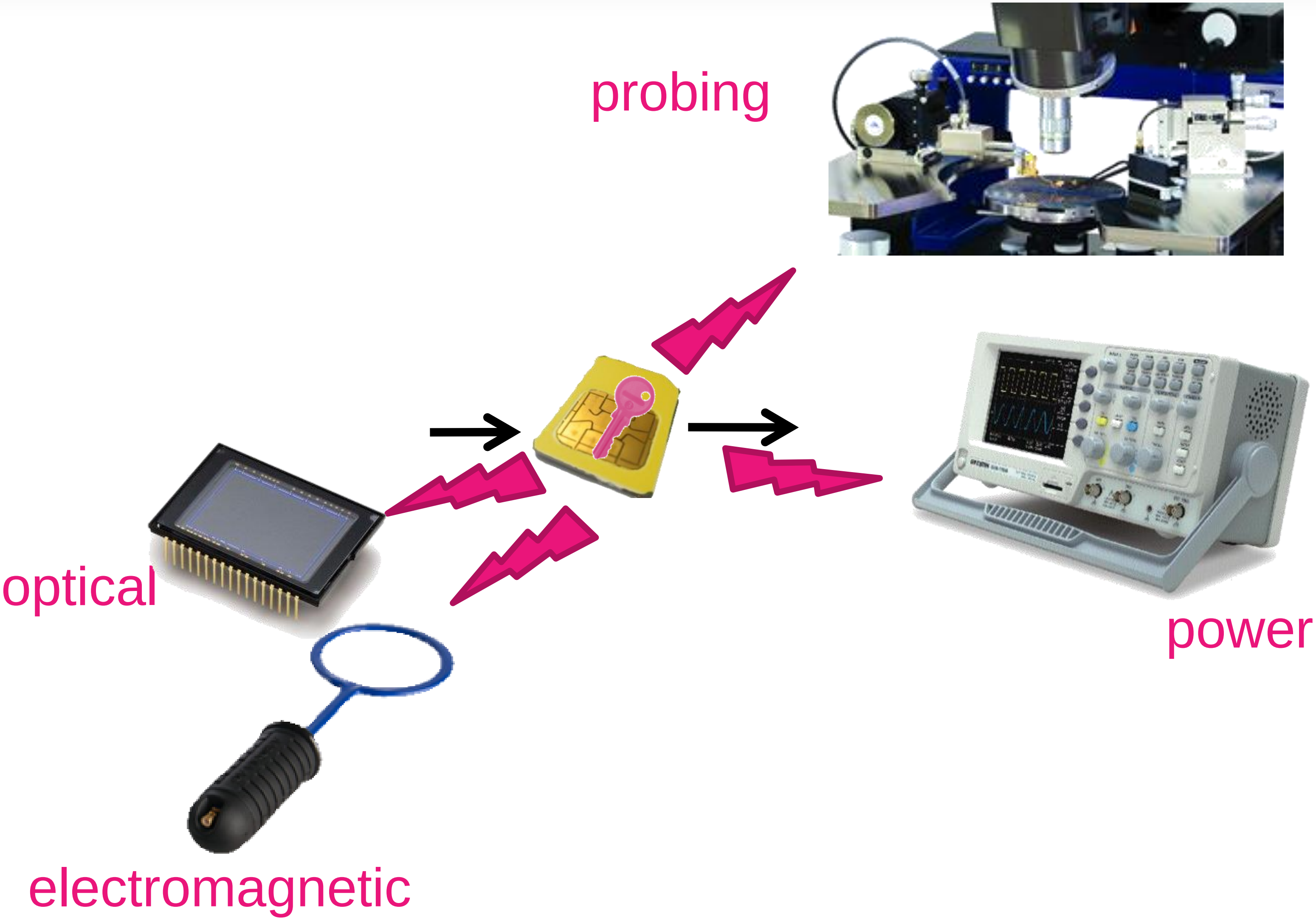

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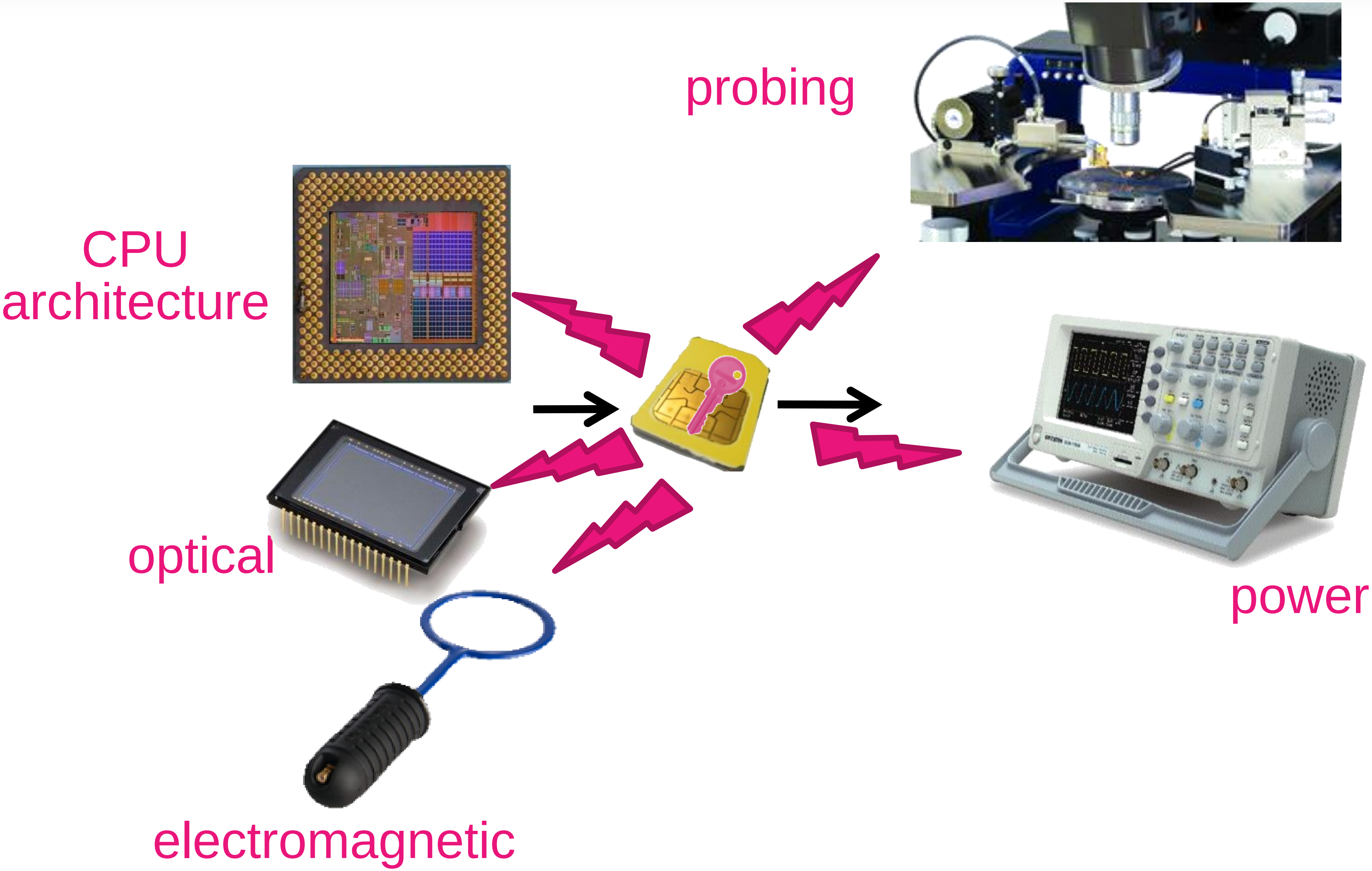

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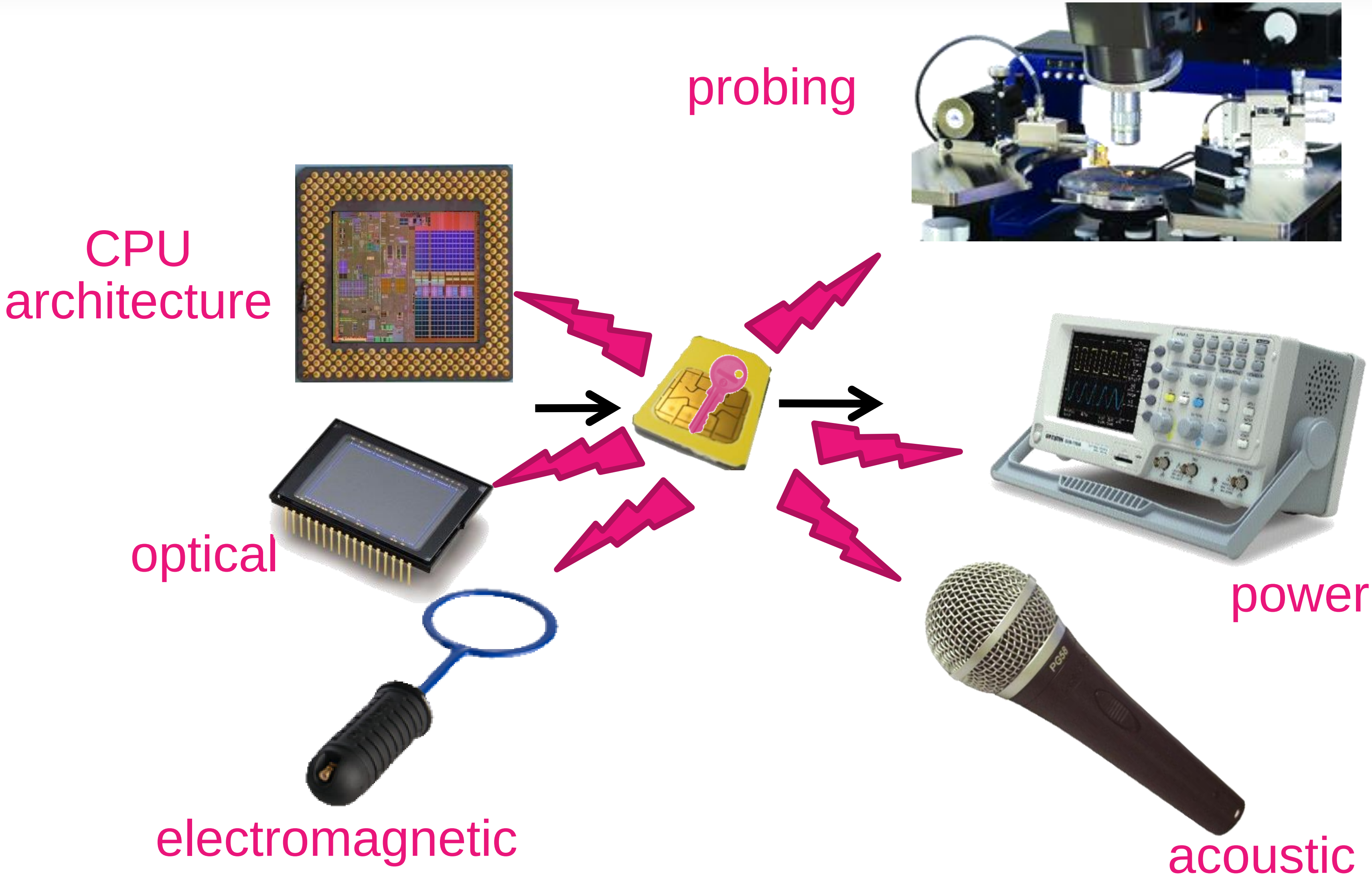

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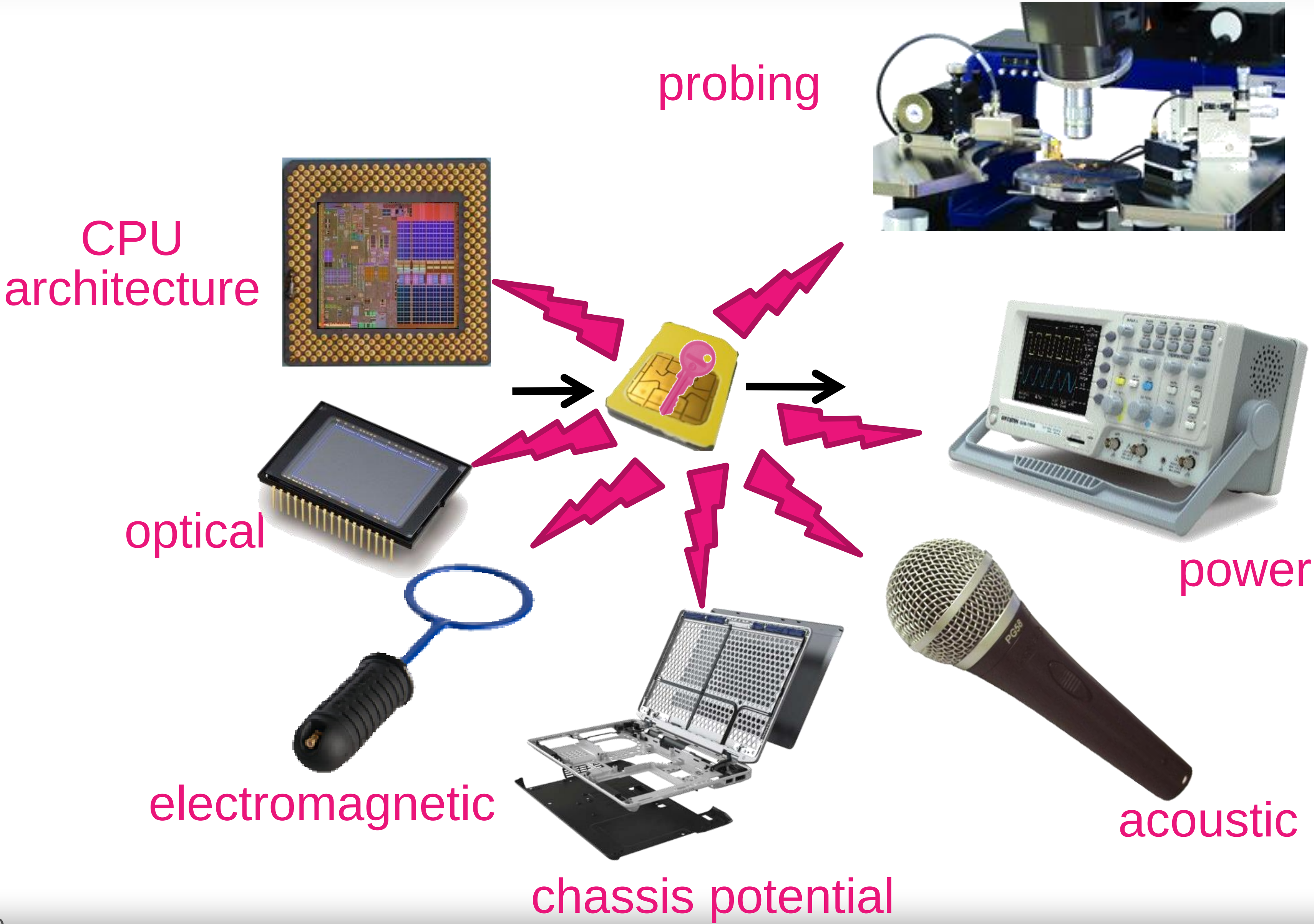

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chassis potential

Traditional side channel attacks methodology

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for i=1…2048
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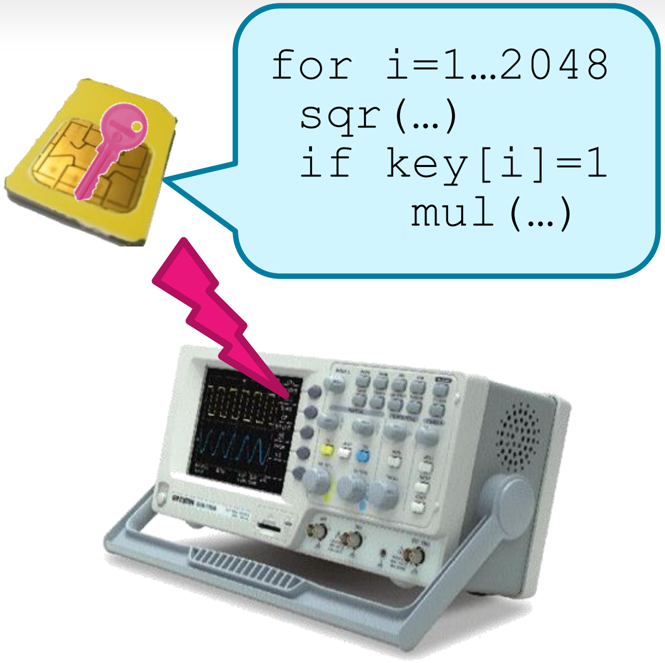

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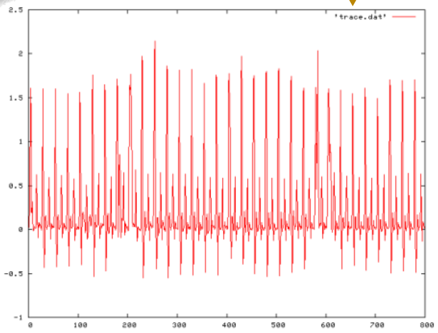

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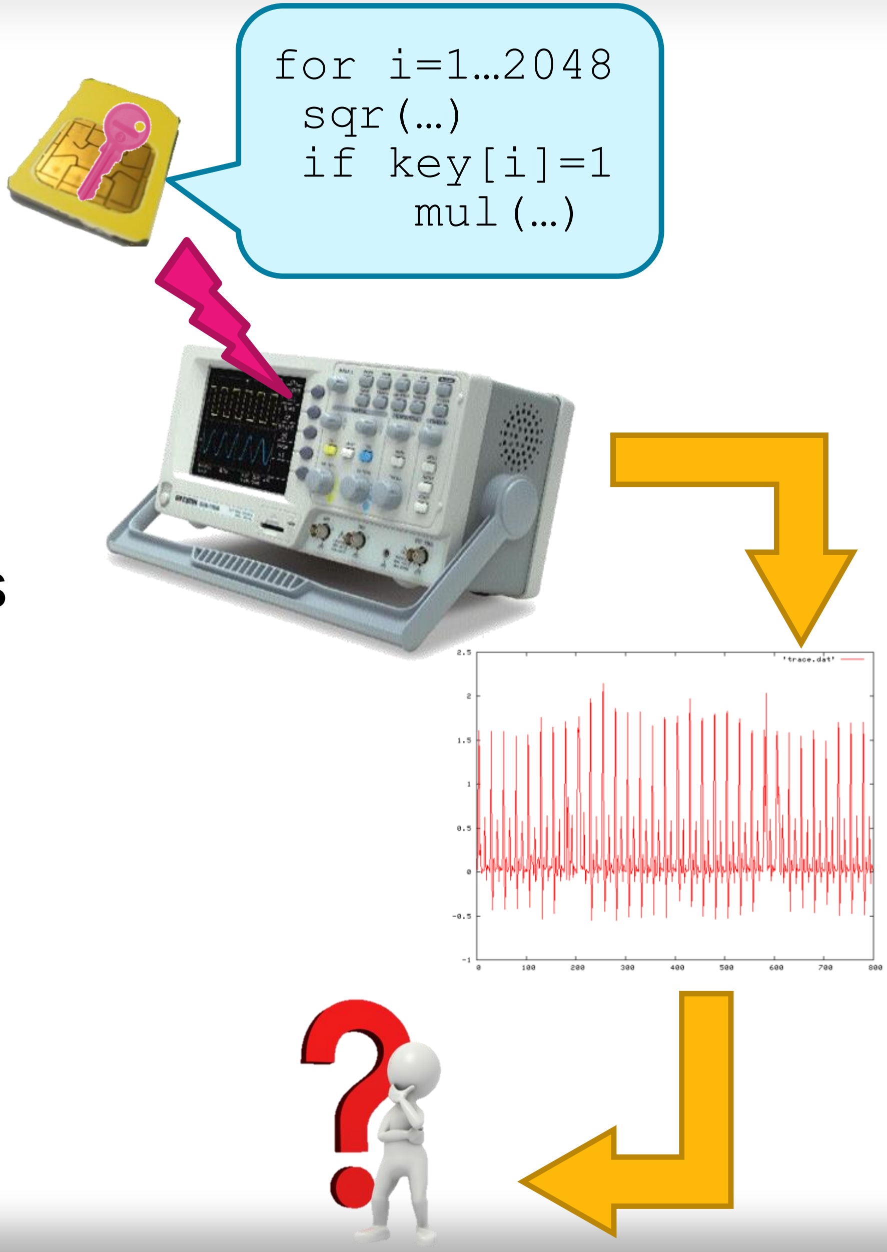

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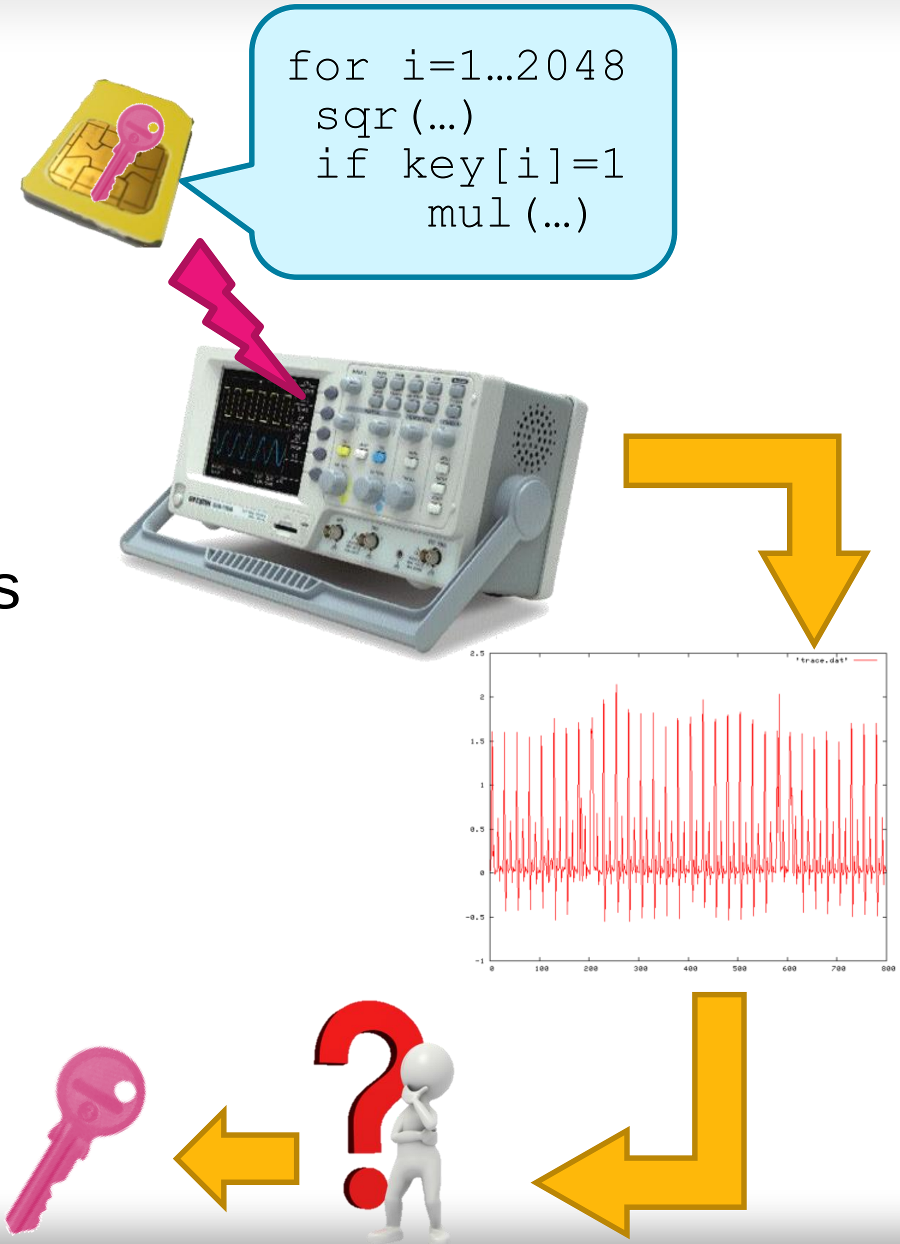

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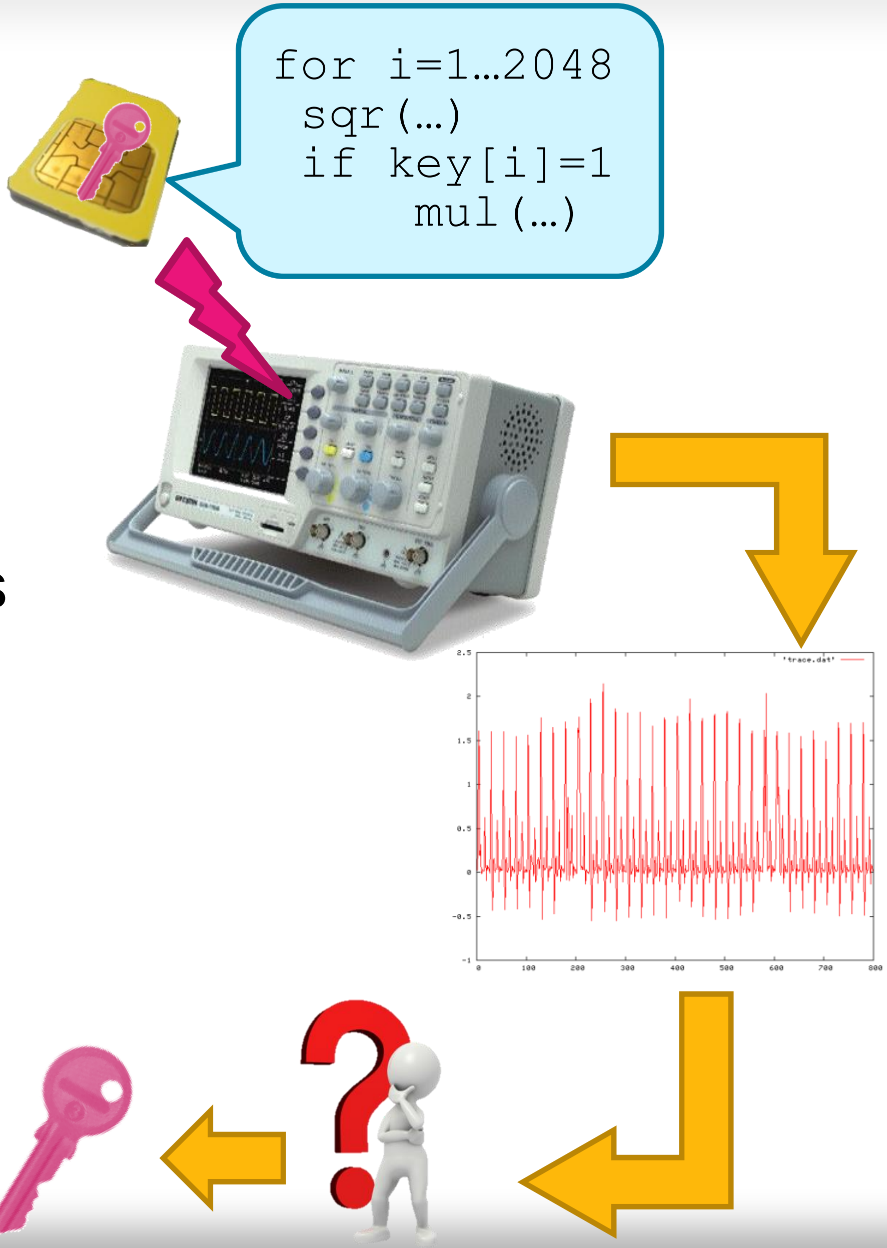

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Measuring a 2GHz PC requires expansive and bulky equipment (compared to a 100 MHz smart card)

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Complex electronics running complicated software (in parallel)

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New channel: Chassis potential

Ground-potential analysis

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  Dump them to the circuit ground!”
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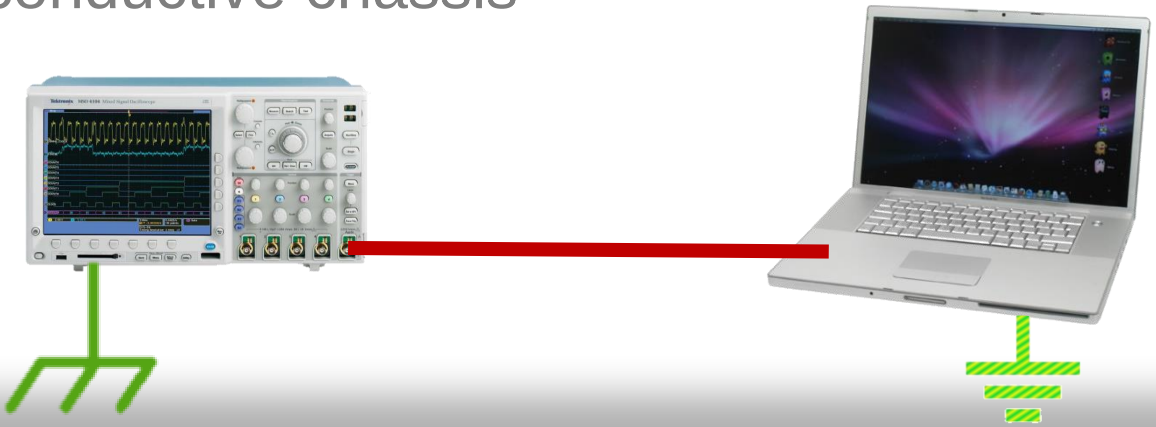

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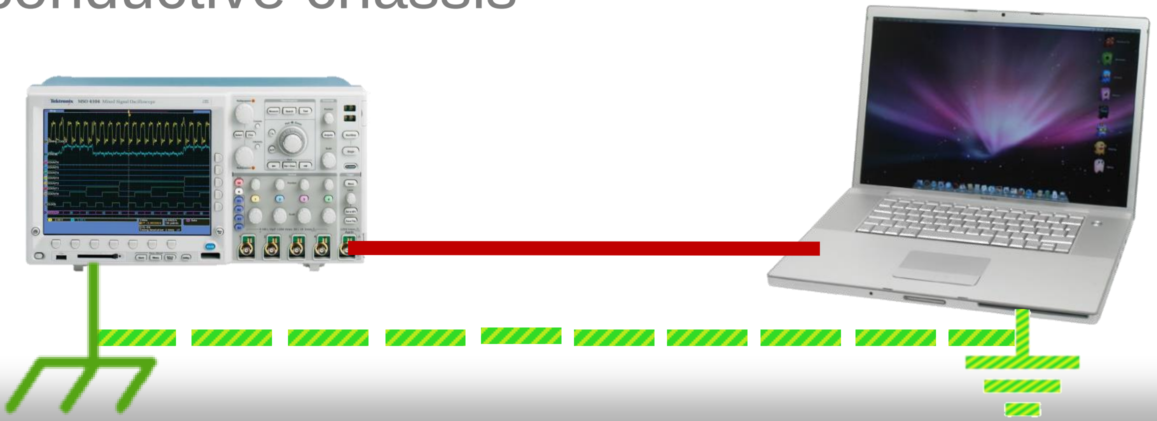

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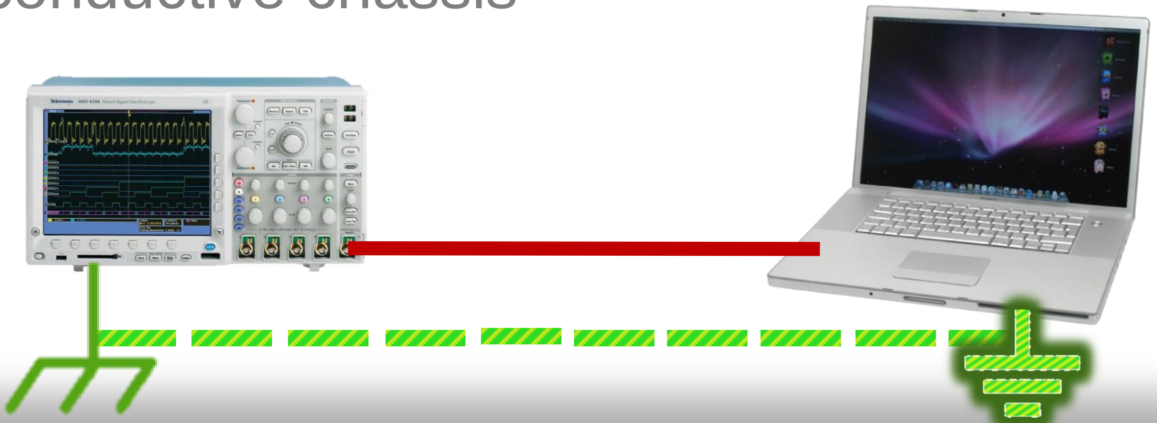

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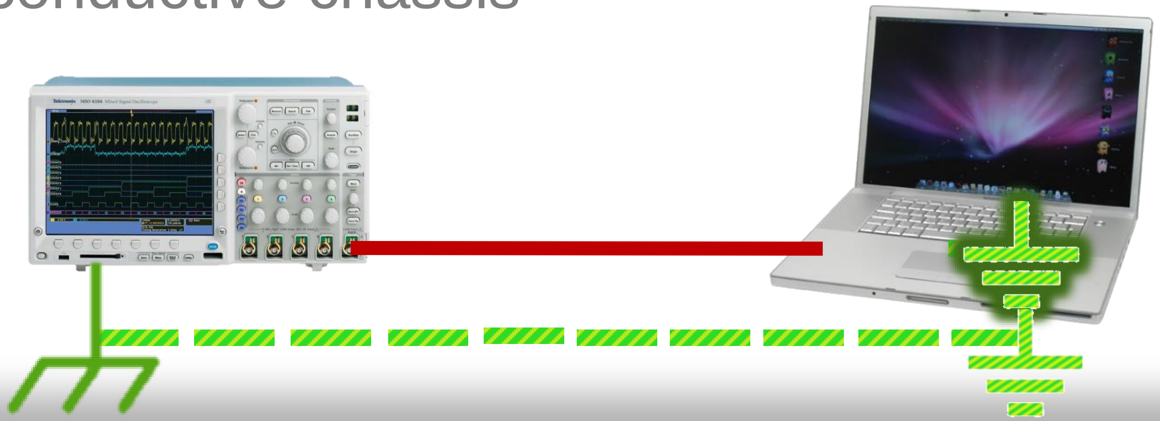

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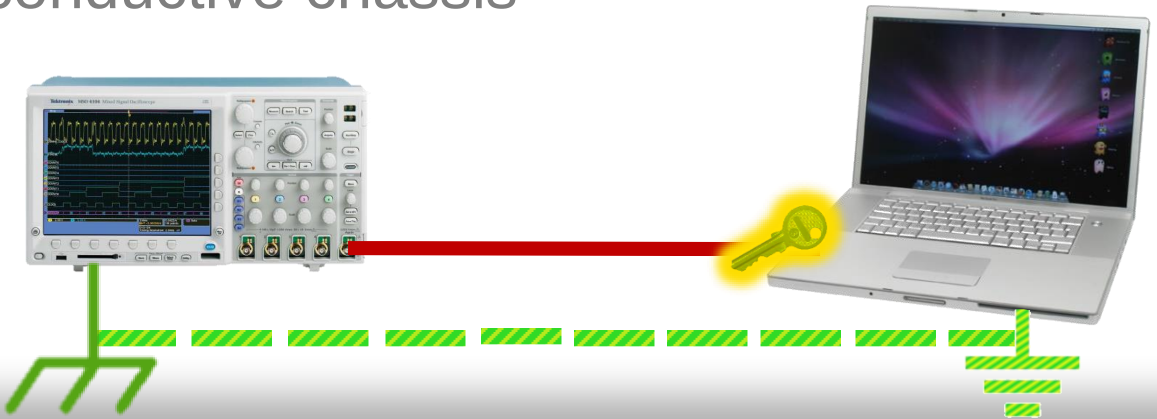

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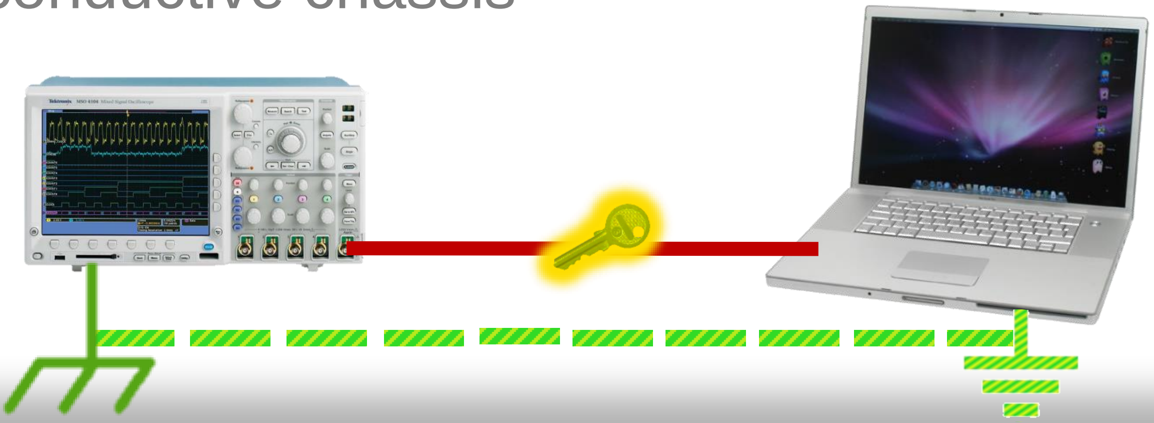

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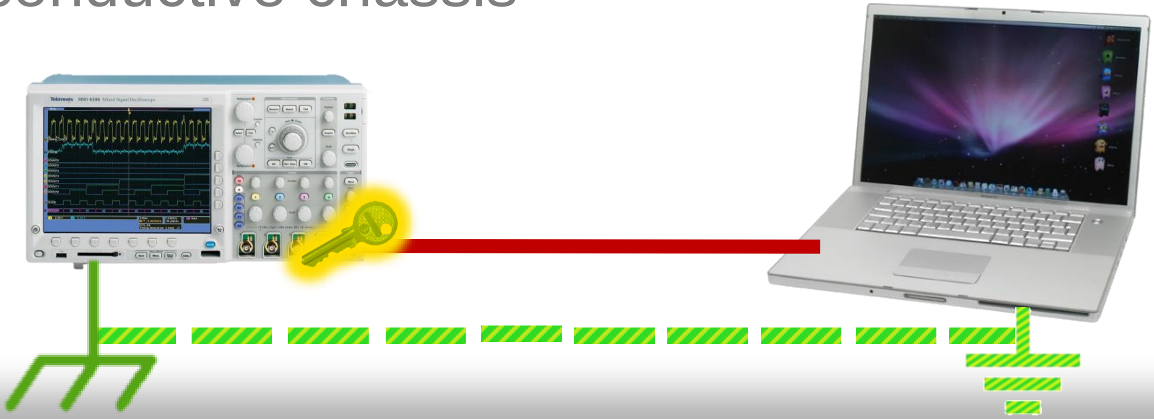

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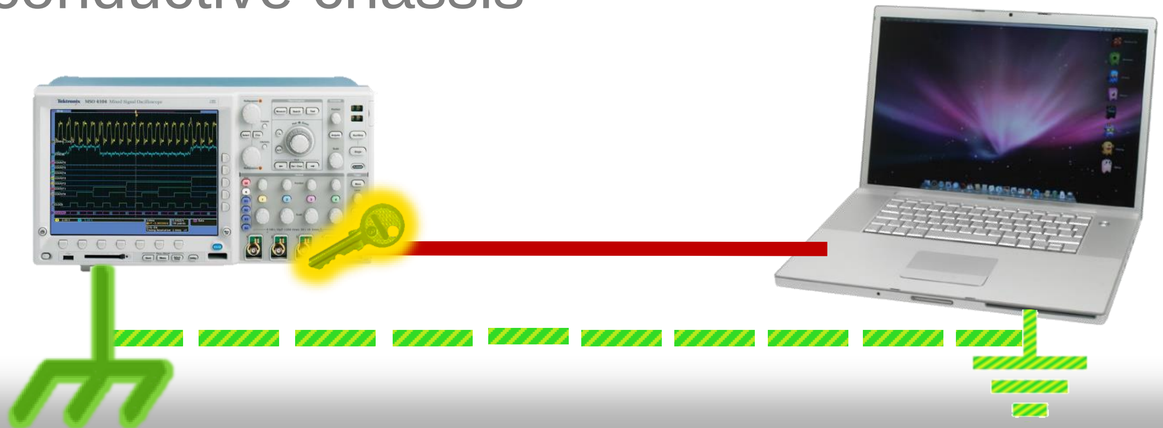

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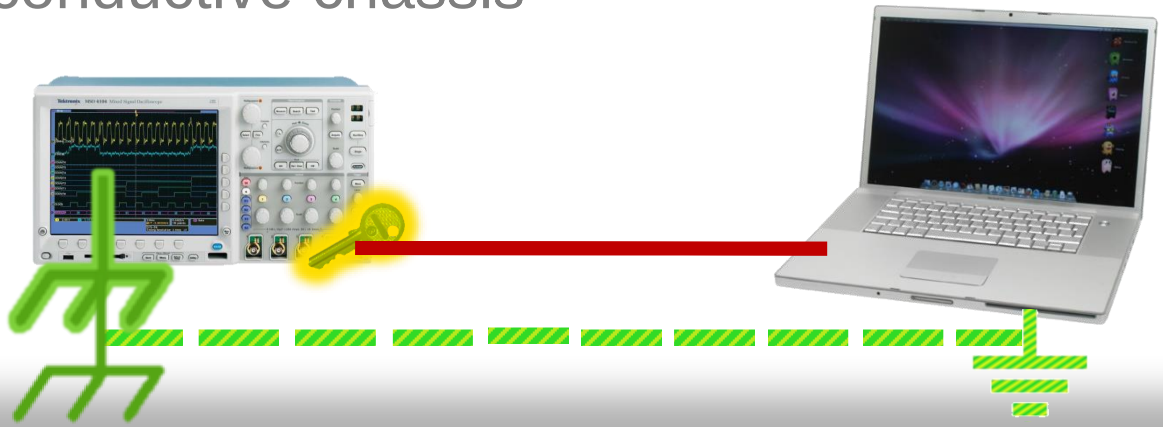

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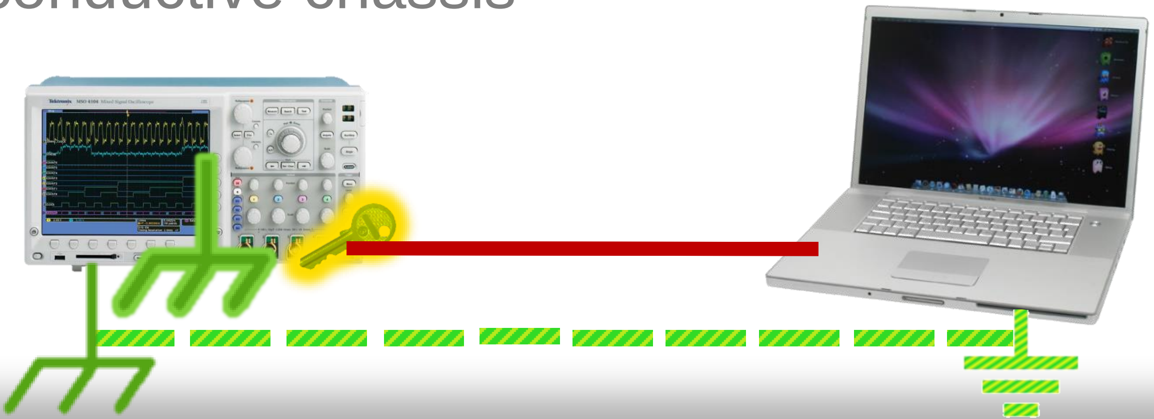

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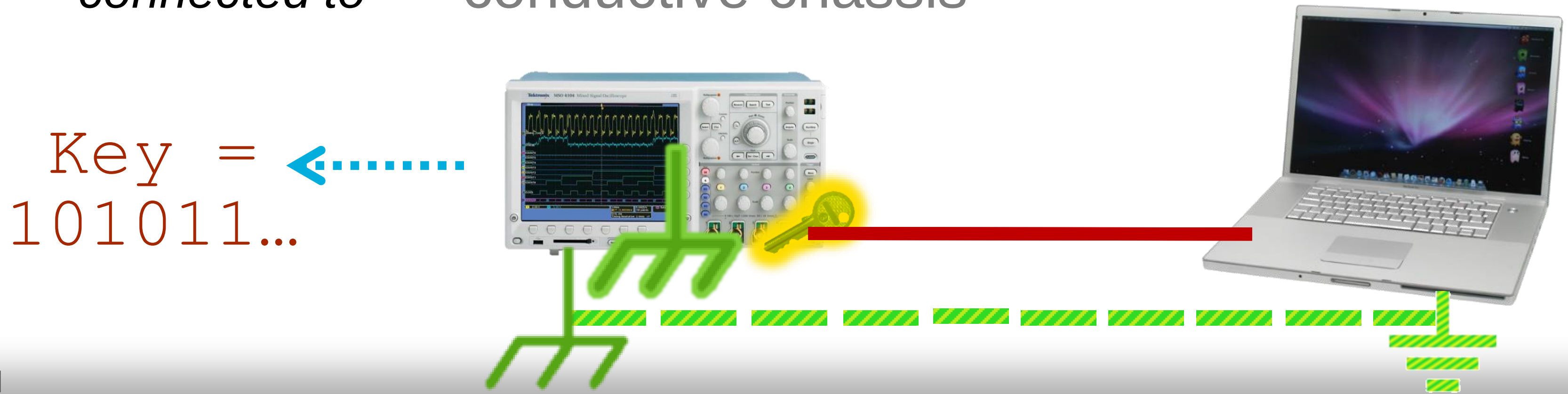

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Demo:
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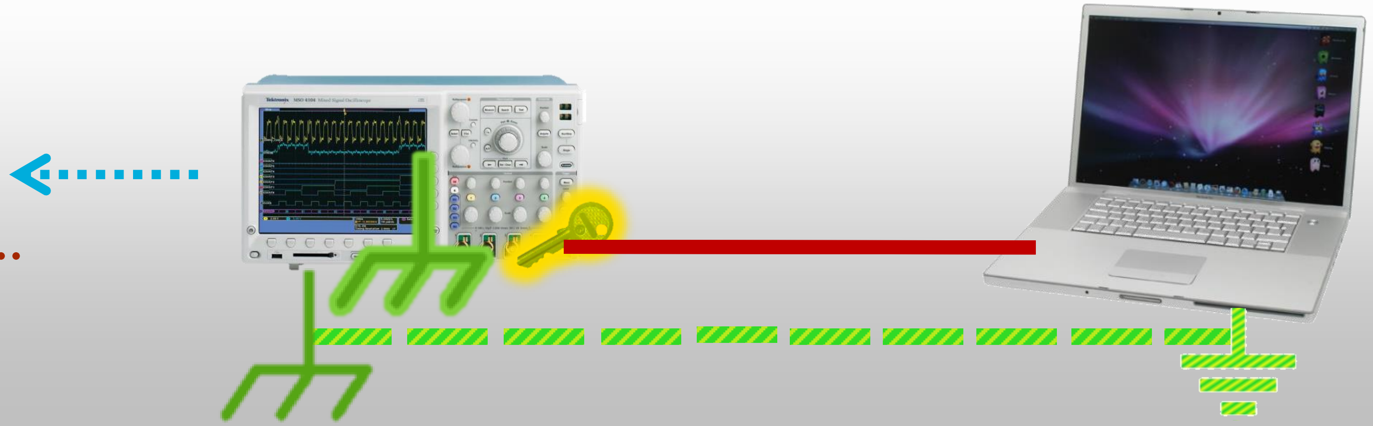
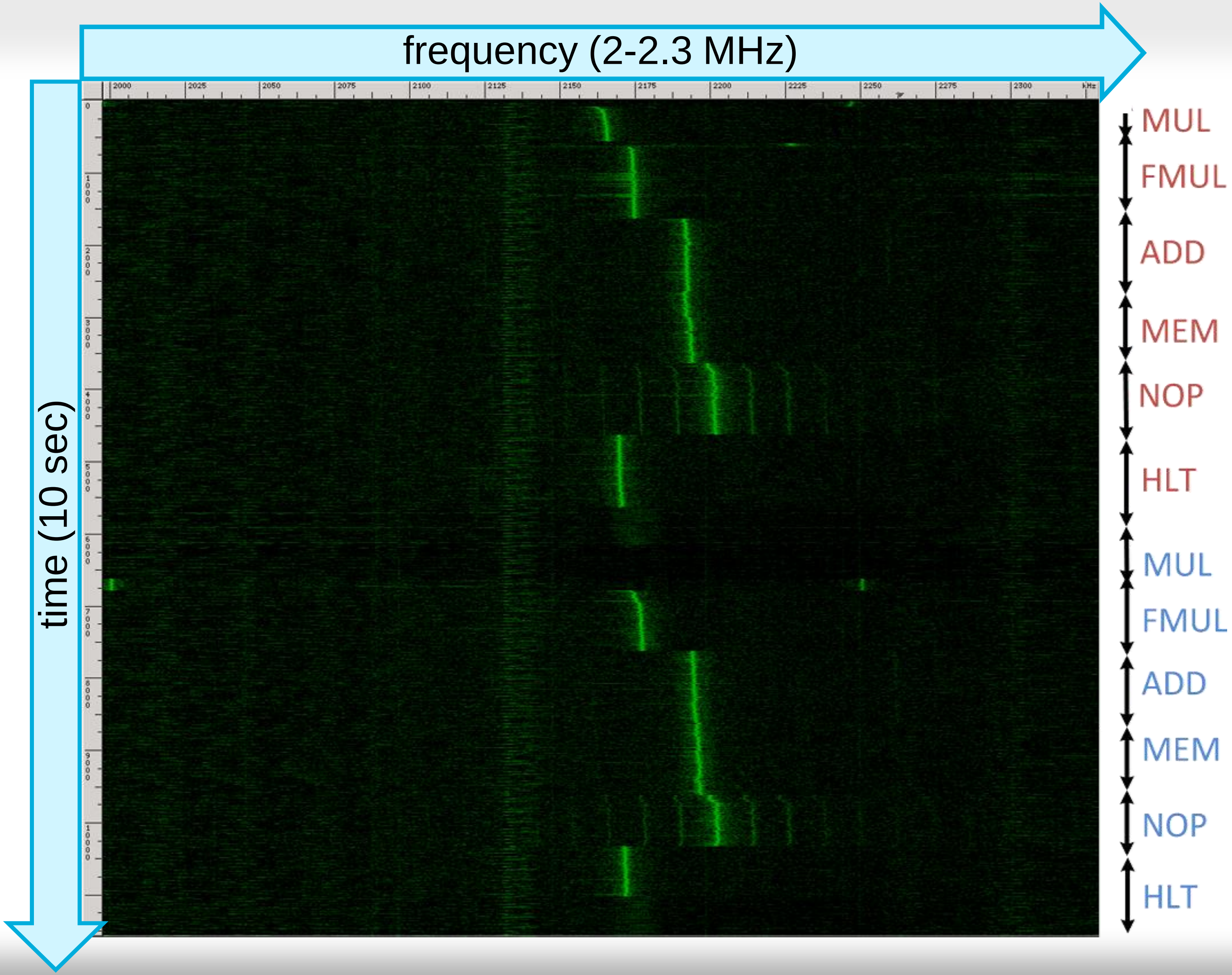


Distinguishing various CPU operations



Low-bandwidth leakage of RSA

Definitions (RSA)

Key setup

- **sk:** random primes p, q, private exponent d
- **pk:** $n = pq$, public exponent e

Encryption

$$c = m^e \, mod \, n$$

Decryption

$$m = c^d \, mod \, n$$

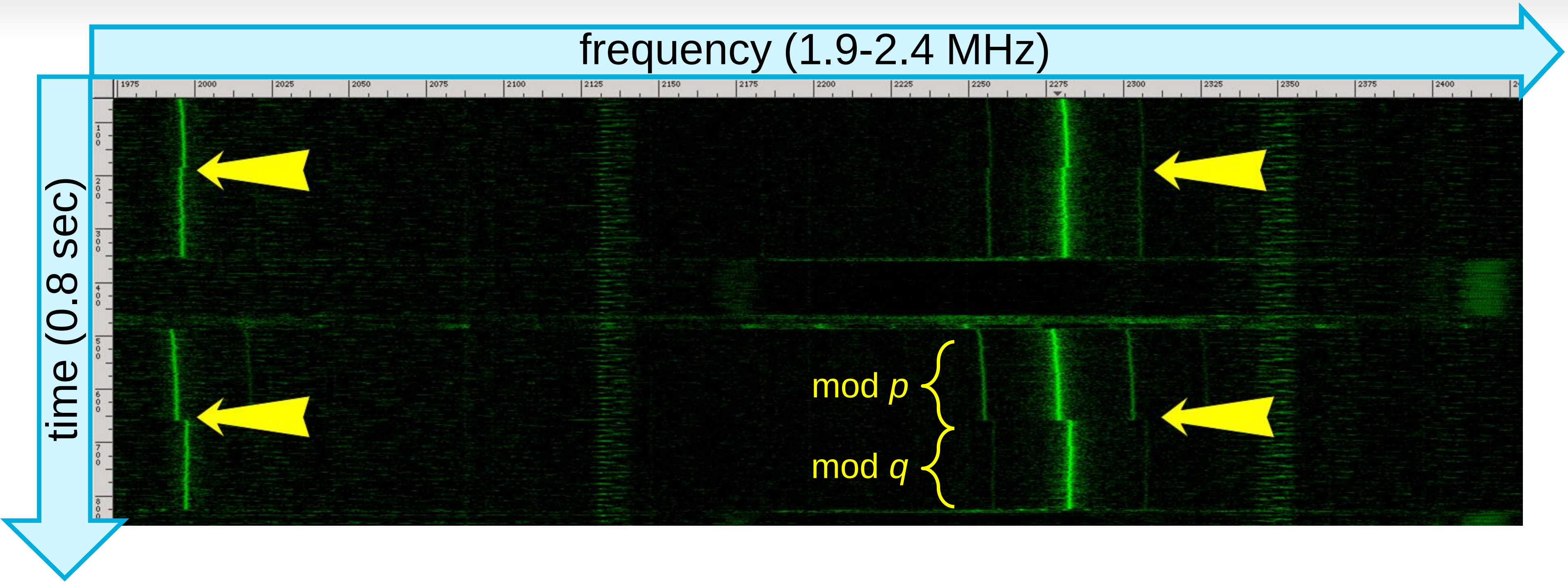
A quicker way used by most implementations

$$m_p = c^{d_p} \, mod \, p$$

$$m_q = c^{d_q} \, mod \, q$$

Obtain m using Chinese Remainder Theorem

GnuPG RSA key distinguishability



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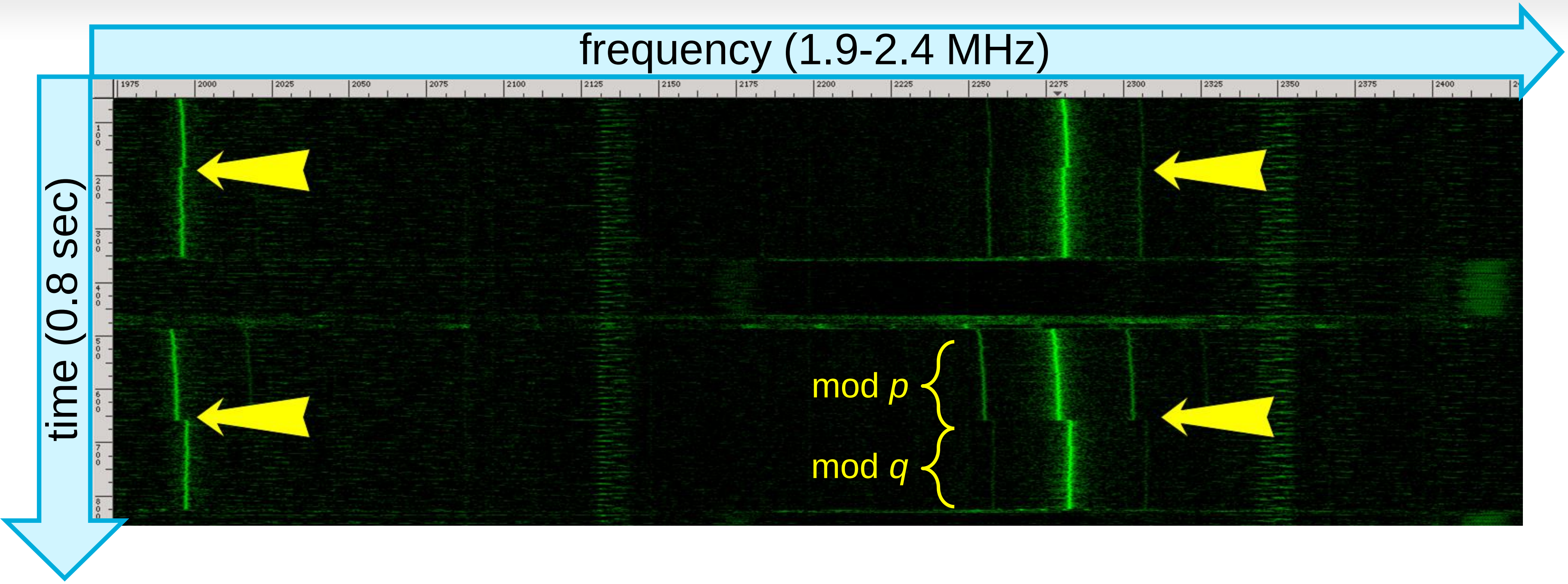

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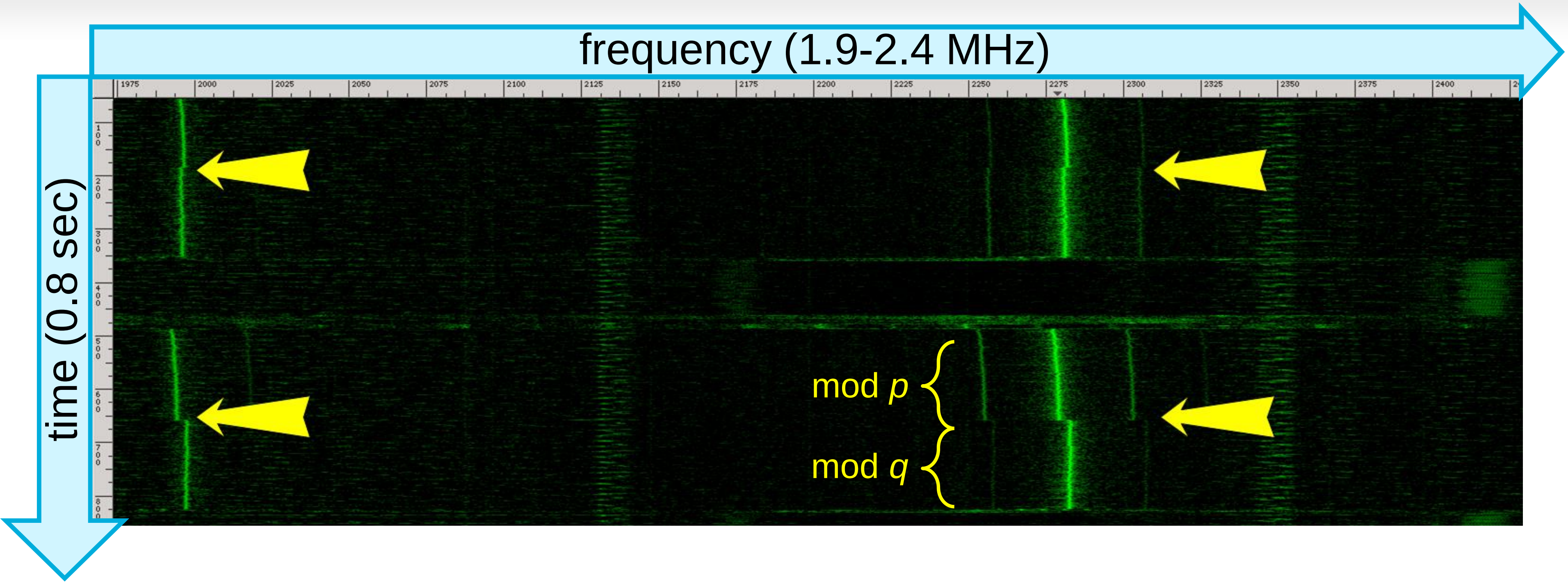

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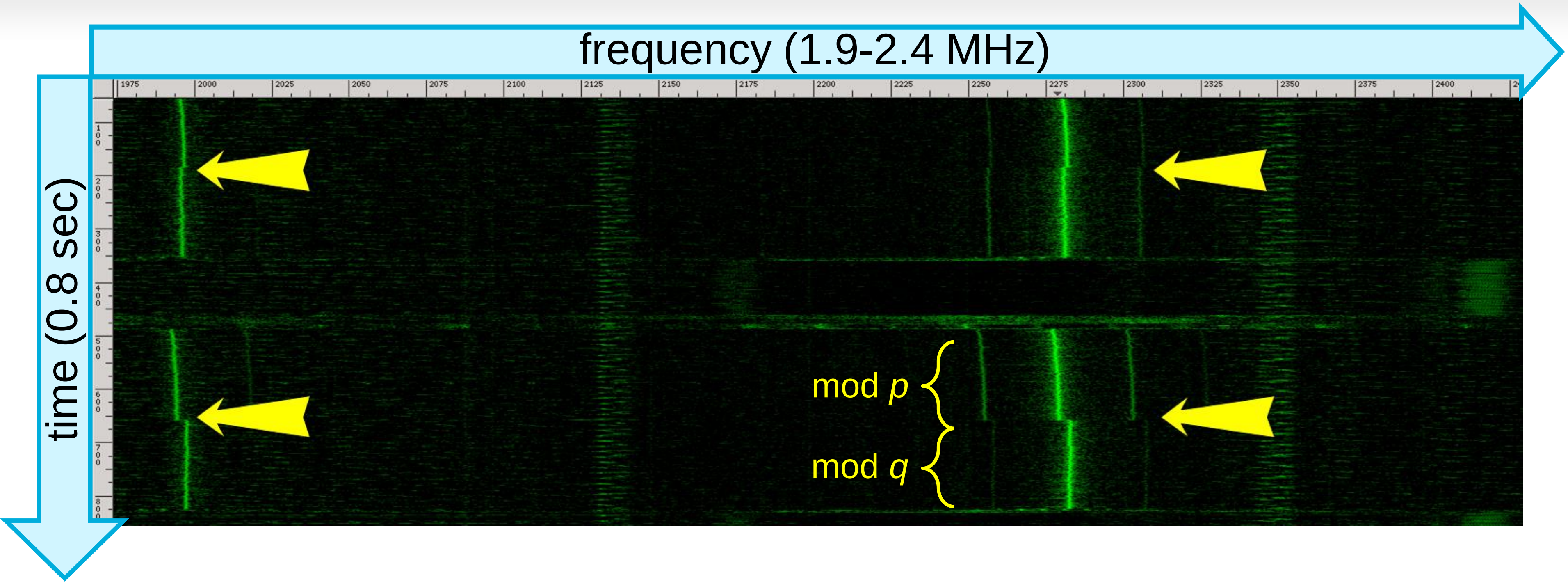

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3. Different keys
4. Different primes

Key extraction

Amplifying the key dependency

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  - **Measure low-bandwidth leakage**

GnuPG modular exponentiation

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modular_exponentiation(c,d,p){
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 for i=1 to n do
  m = $m^2$ mod p
  t = m*c mod p //always mult
  if d[i]=1 then
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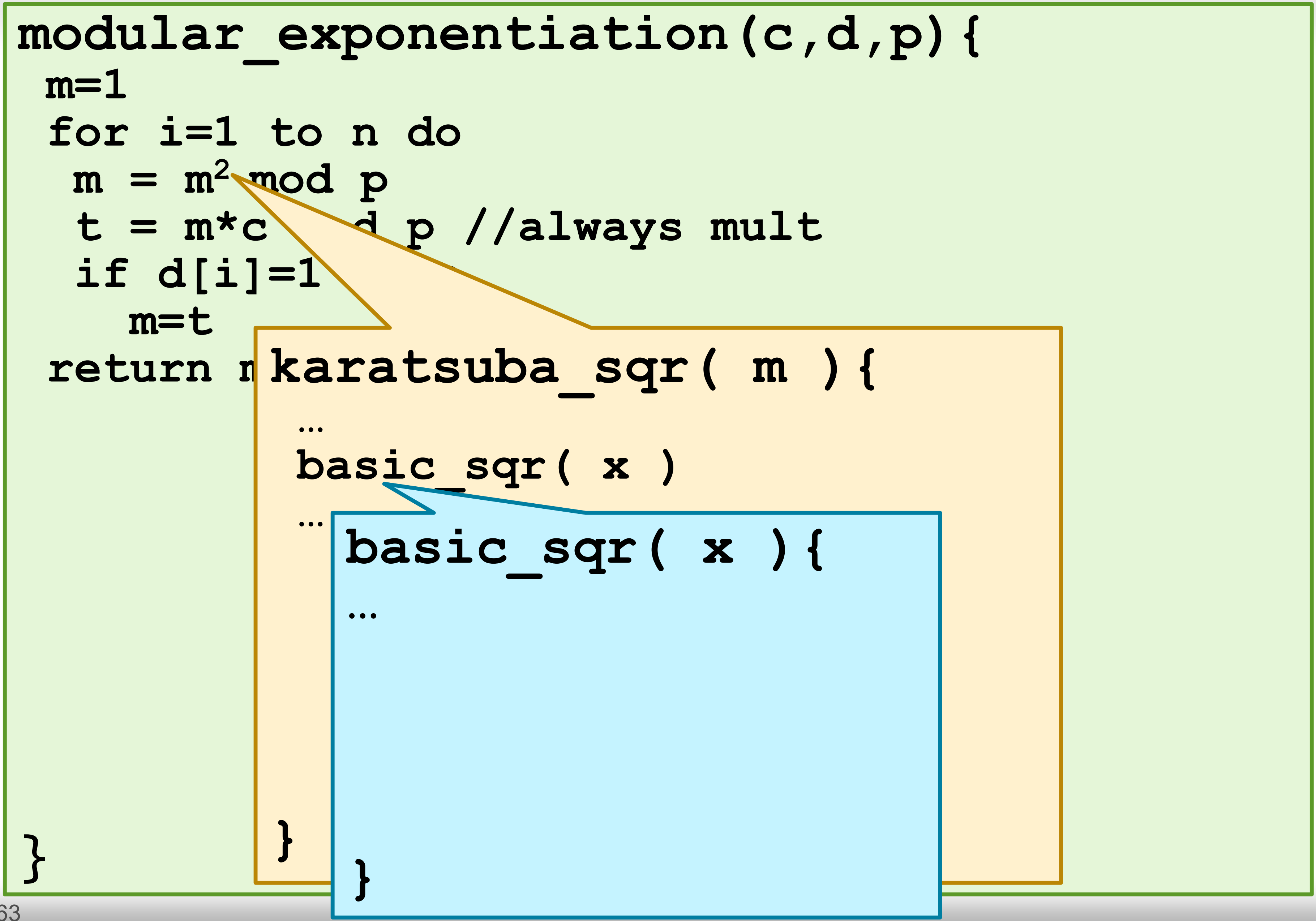

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if( x[j]==0)
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else
 y = x[j]*x
```

```
}
```

GnuPG modular exponentiation

```
modular_exponentiation(c,d,p){
 m=1
 for i=1 to n do
  m = m^2 mod p
  t = m*c    d p //always mult
  if d[i]=1
    m=t
 return m
}
```

```
karatsuba_sqr( m ){
  …
  basic_sqr( x )
  …
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x7

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x27

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}
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x7

GnuPG modular exponentiation

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 m=1
 for i=1 to n do
  m = $m^2$ mod p
  t = m*c    d p //always mult
  if d[i]=1
    m=t
 return m
}
```

```
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repeated 189 times per bit of d

~0.2ms of measurement per bit of d

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}
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x27

x7

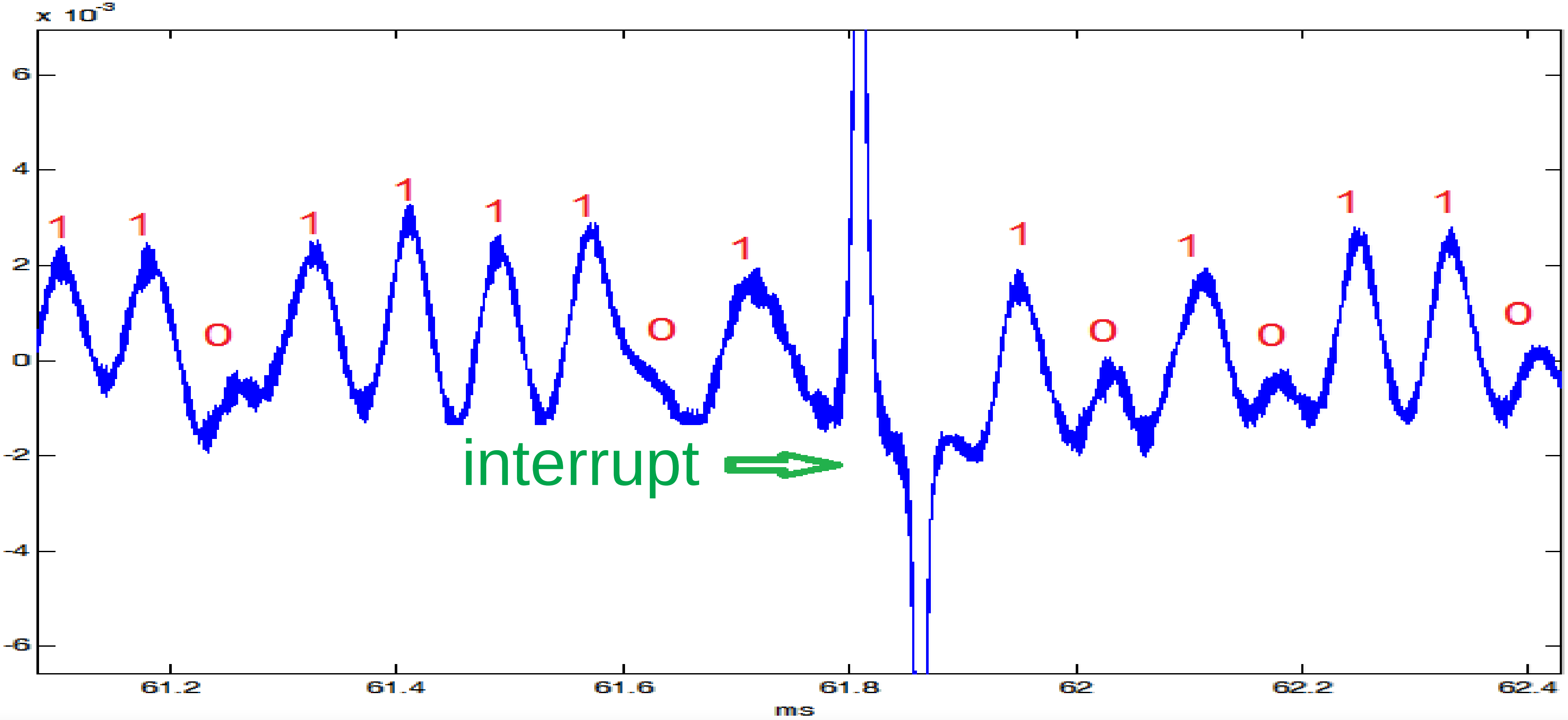
repeated 189 times per bit of d

~0.2ms of measurement per bit of d

craft c such that
$d[i] = 1 \rightarrow x[j] = 0$
$d[i] = 0 \rightarrow x[j] \neq 0$
(for most j's)

Reading the secret key (non-adaptive attack)

- Acquire trace
- Filter around carrier (1.7 MHz)
- FM demodulation
- Read out bits (“simple ground analysis”)



A chosen ciphertext attack

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- Total #measurements:

Attack type	# of traces	Time	Bandwidth	Cipher

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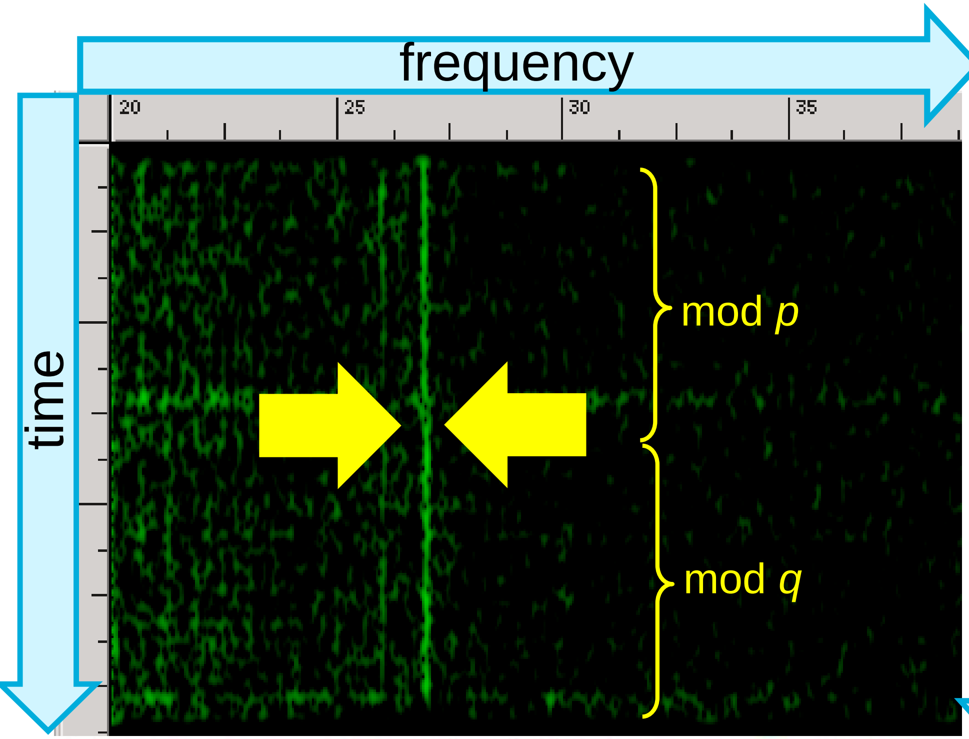
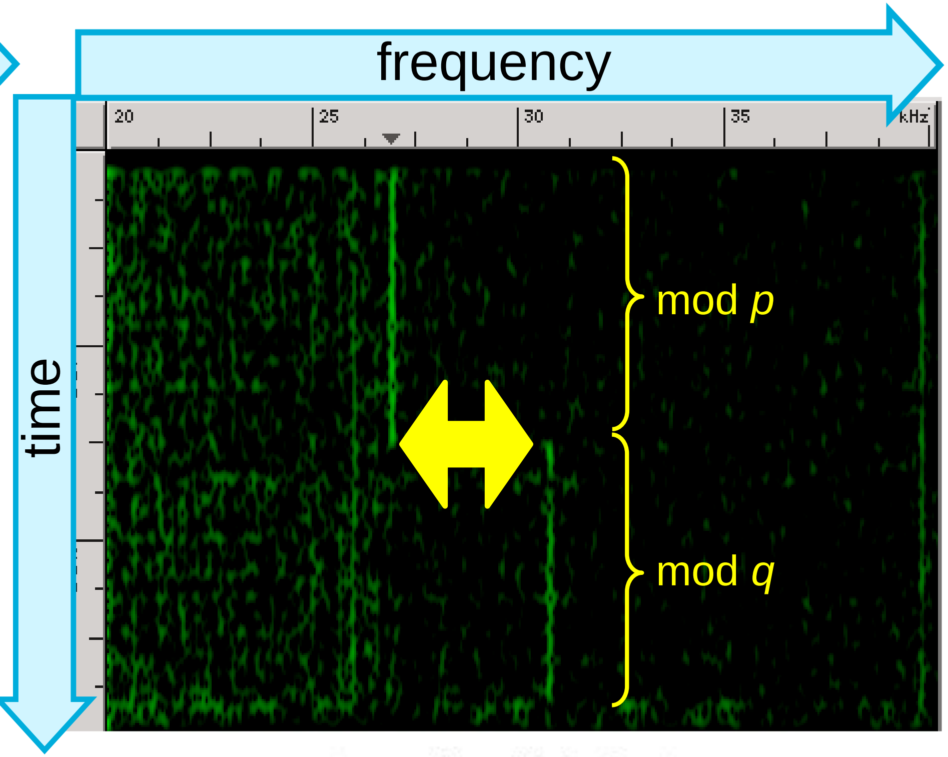
- Send chosen ciphertexts using Enigmail

Empirical results

Reading the secret key (adaptive attack)



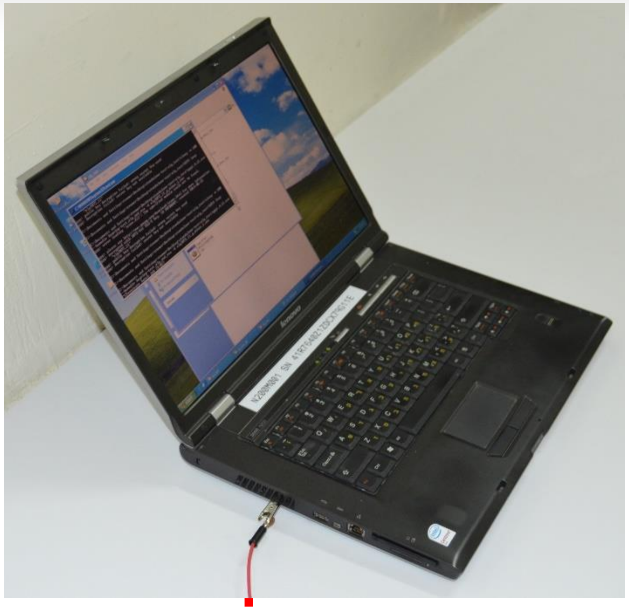
Attacked bit is 0

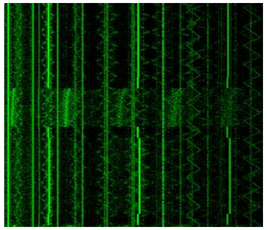


Attacked bit is 1

Demo:
key extraction

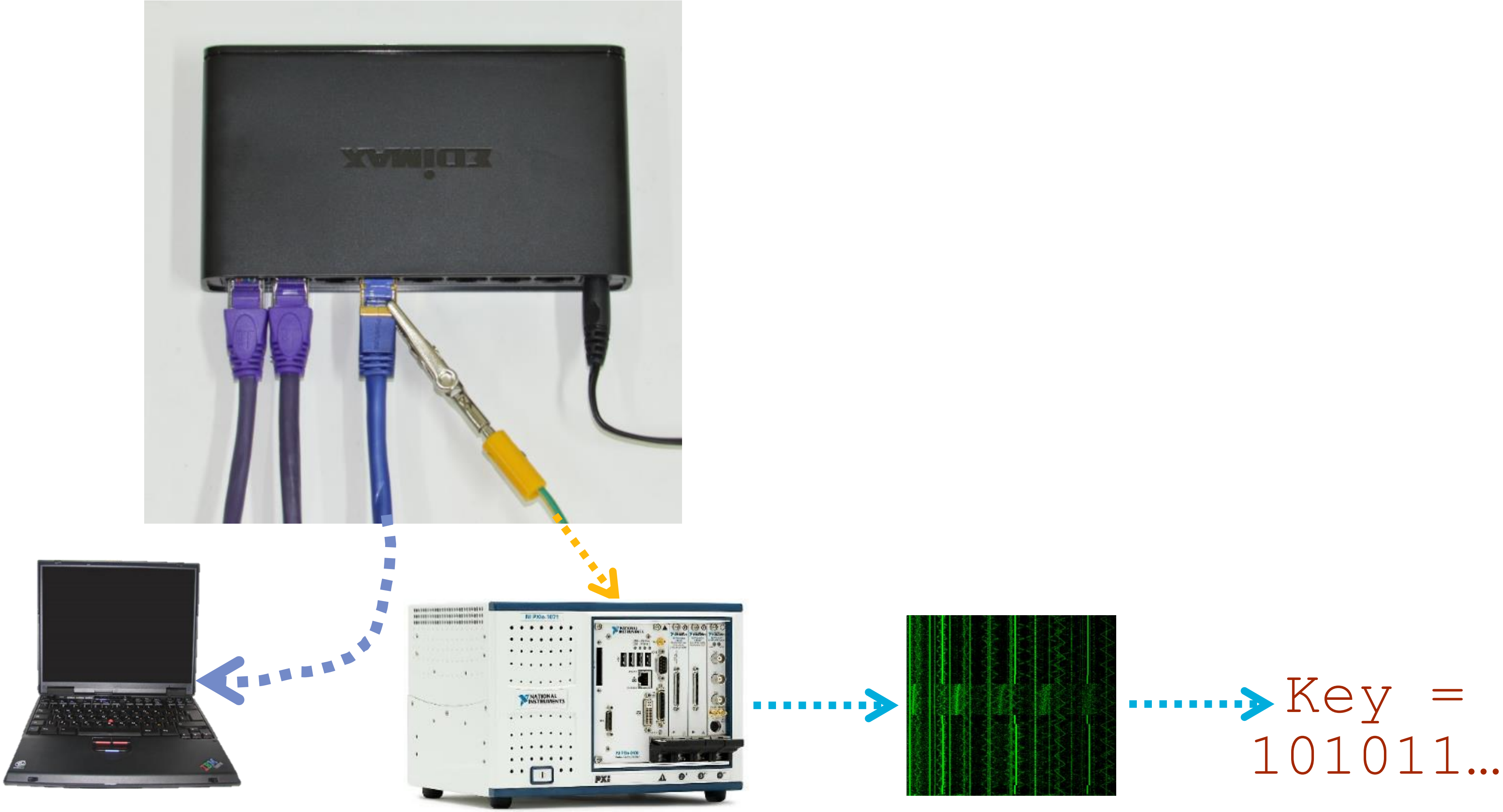
RSA and ElGamal key extraction in a few seconds using direct chassis measurement (non-adaptive attack)





Key = 101011…

RSA and ElGamal key extraction in a few seconds using the far end of 10 meter network cable (non-adaptive attack)



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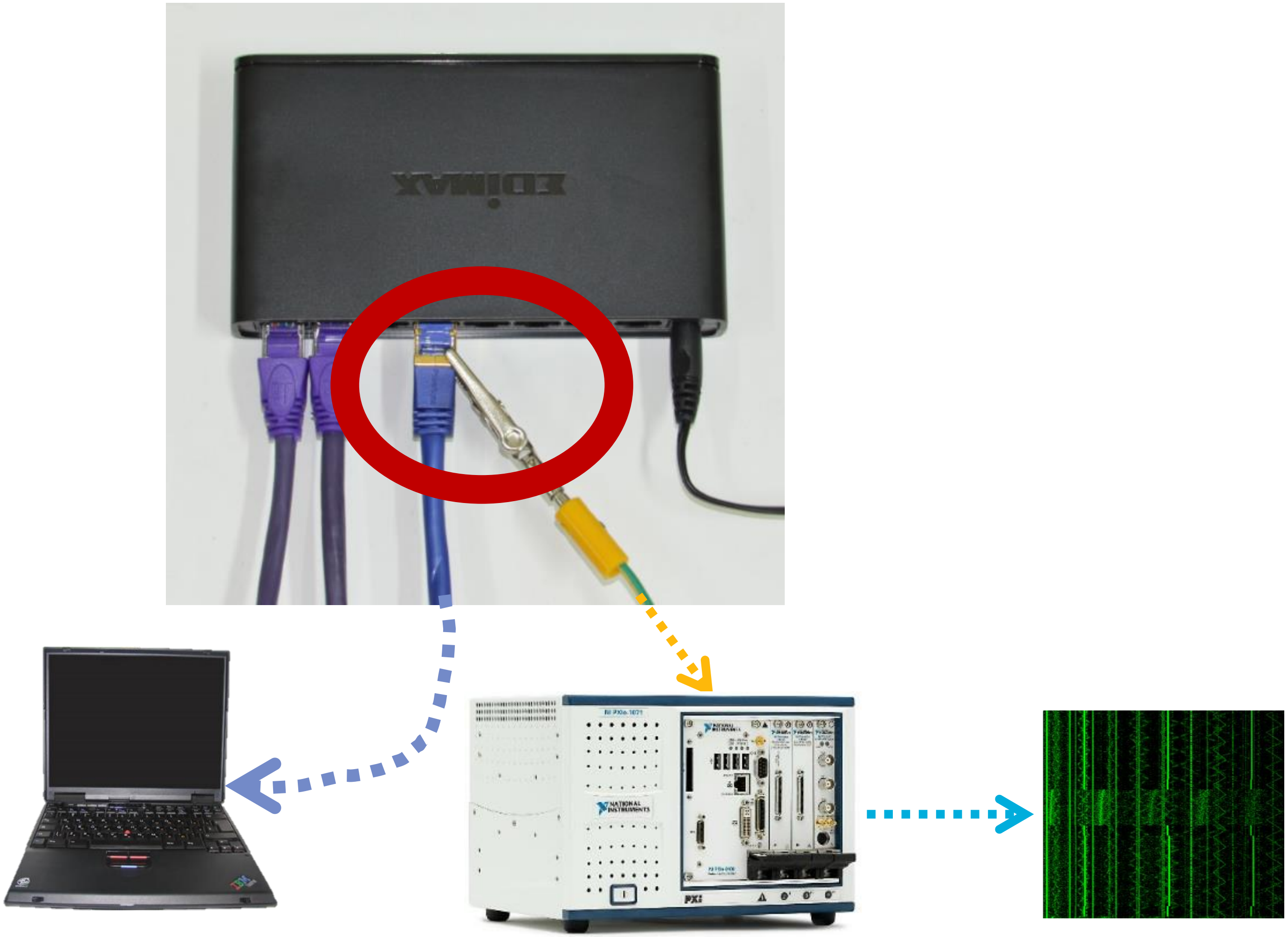
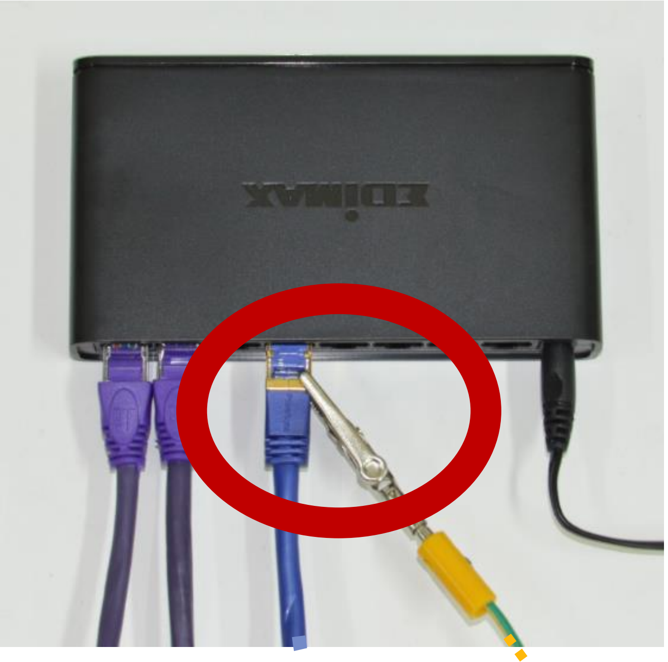
RSA and ElGamal key extraction in a few seconds using the far end of 10 meter network cable (non-adaptive attack)

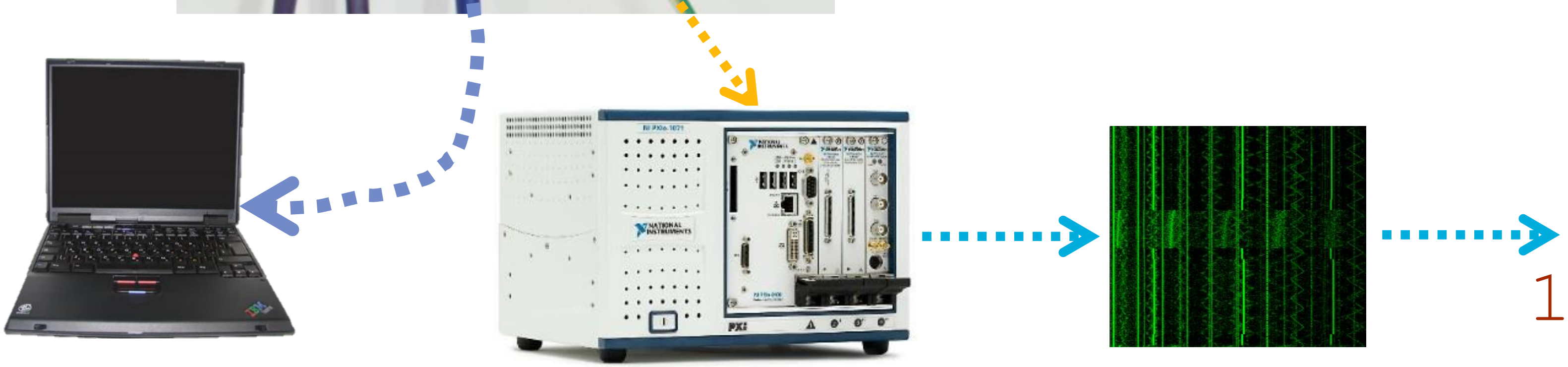


Key = 101011…

RSA and ElGamal key extraction in a few seconds using the far end of 10 meter network cable (non-adaptive attack)

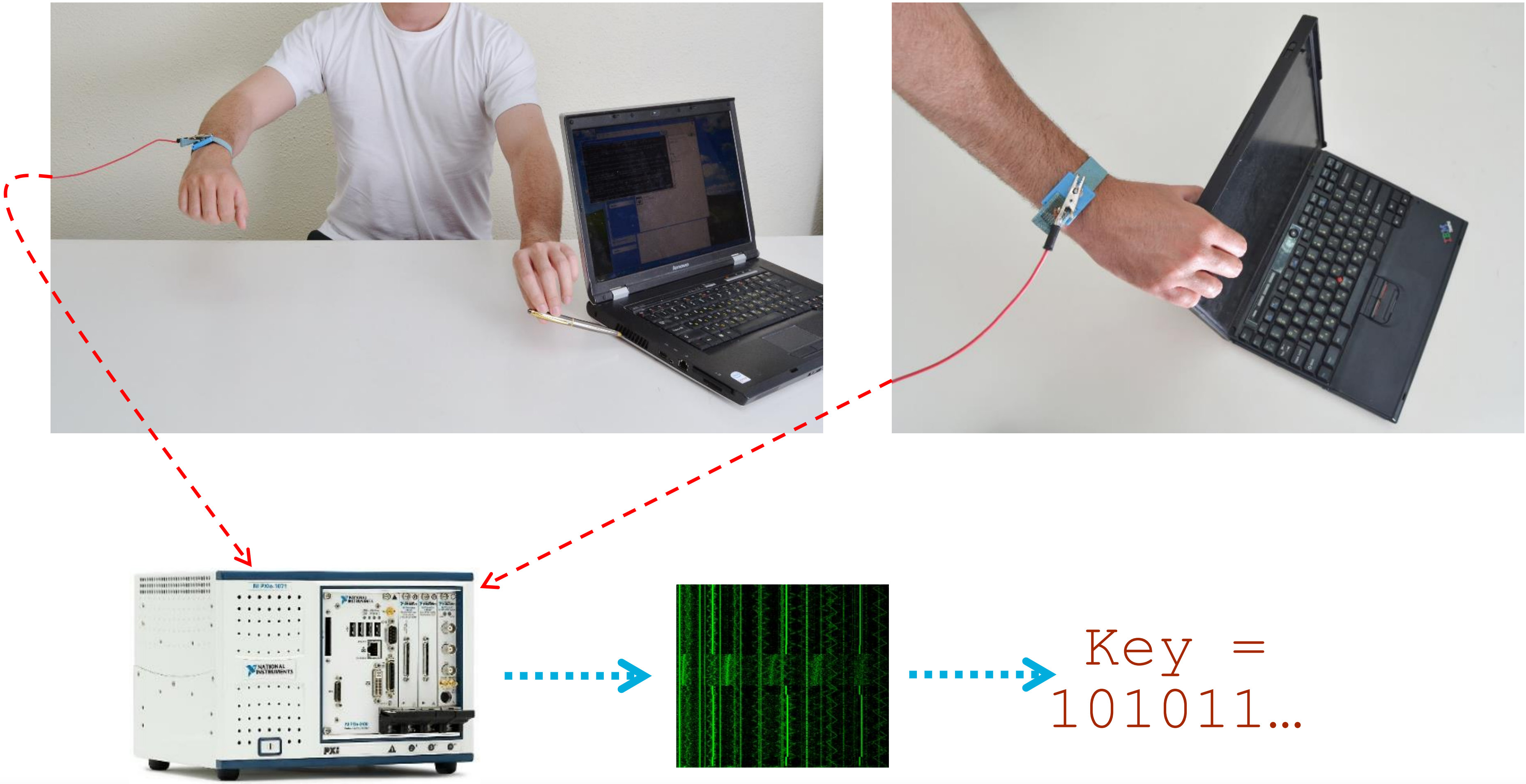


works even if a firewall is present, or port is turned off



Key = 101011…

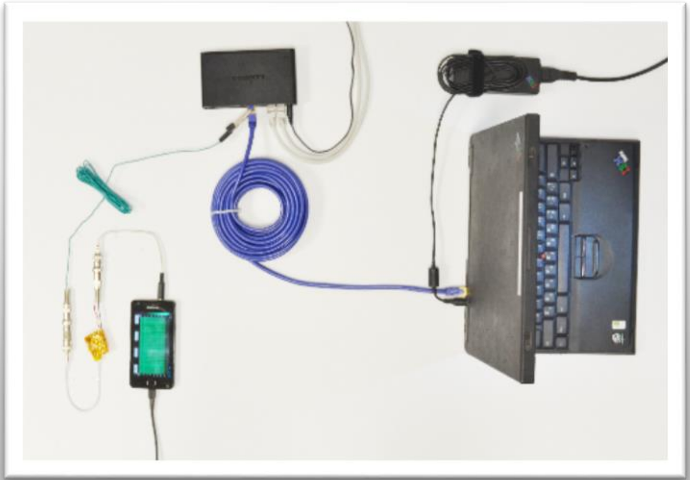
RSA and ElGamal key extraction in a few seconds using human touch (non-adaptive attack)



Key = 101011…

Thanks!

cs.tau.ac.il/~tromer/handsoff



Thanks!

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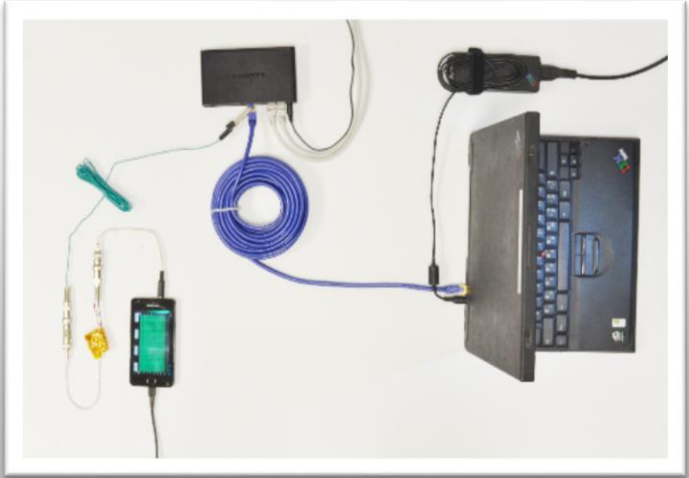

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