Auswertung

November 24, 2023

0.0.1 Vorbereitungen

yum install texlive-collection-latexextra texlive-collection-mathscience python-pip pandoc

pip install –user notebook pandas seaborn scipy

[1]:
```
import math
import pandas as pd
import seaborn as sns
from matplotlib import pyplot as plt
from scipy.stats import linregress
```

[2]:
```
sns.set_theme(context='paper', style="whitegrid", color_codes=True)
```

[31]:
```
H_column = r'$H$ in $10^3 \frac{A}{m}$'
H_column_detailed = r'$H$ in $\frac{A}{m}$'
I_column = r'$I_{max}$ in A'
M_column = r'M in $10^6\ \frac{A}{m}$'
M_column_detailed = r'M in $10^3\ \frac{A}{m}$'
```

[4]:
```
def plot(data, hue_column=I_column, filename=None):
    img = sns.relplot(
        data=data,
        x=H_column,
        y=M_column,
        hue=hue_column,
        height=5,
        legend='full'
    )
    if filename is not None:
        img.figure.savefig(filename, bbox_inches='tight')
```

[32]:
```
def subplot(data, x_column=H_column, y_column=M_column, axis=None):
    return sns.scatterplot(
        data=data,
        x=x_column,
        y=y_column,
        hue=I_column,
        marker='x',
```

```
        ax=axis
    )
```

0.1 3.3.1

[6]:
```
heizbar_a = pd.read_csv("3.3.1.a.csv", sep='\t')
heizbar_b = pd.read_csv("3.3.1.b.csv", sep='\t')
heizbar_c = pd.read_csv("3.3.1.c.csv", sep='\t')
heizbar_d = pd.read_csv("3.3.1.d.csv", sep='\t')
```

[7]:
```
def H(U):
    U_max = heizbar_a.H.max()
    n_p=17
    r=1.5/100 # m
    return n_p/(2 * math.pi * r) * (3.0/U_max) * U / 1e3
```

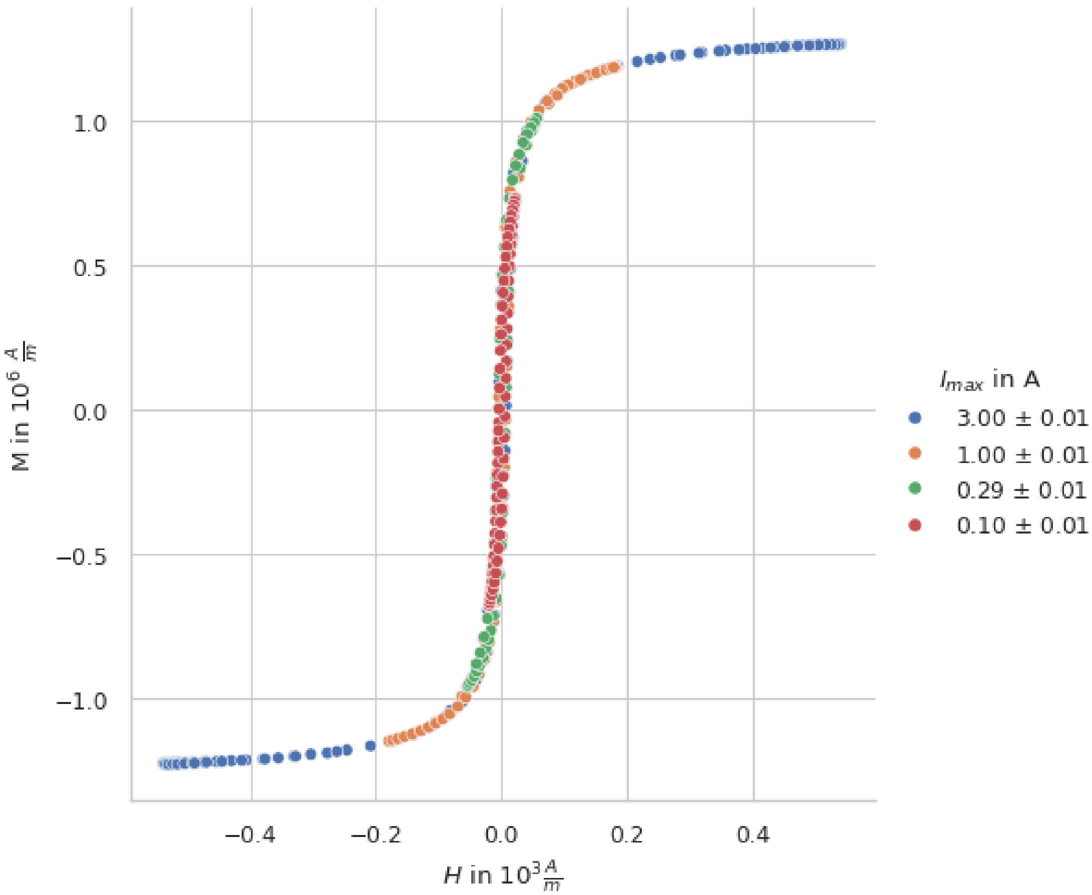
[8]:
```
def M(U):
    nu = 50 # Hz
    n_s = 17
    q = 0.9/10000 # m^2
    mu_0 = 4* math.pi * 1e-7
    return U / (47*nu*n_s*q*mu_0) / 1e6
```

[9]:
```
heizbar_a[I_column] = r'3.00 $\pm$ 0.01'
heizbar_b[I_column] = r'1.00 $\pm$ 0.01'
heizbar_c[I_column] = r'0.29 $\pm$ 0.01'
heizbar_d[I_column] = r'0.10 $\pm$ 0.01'
```

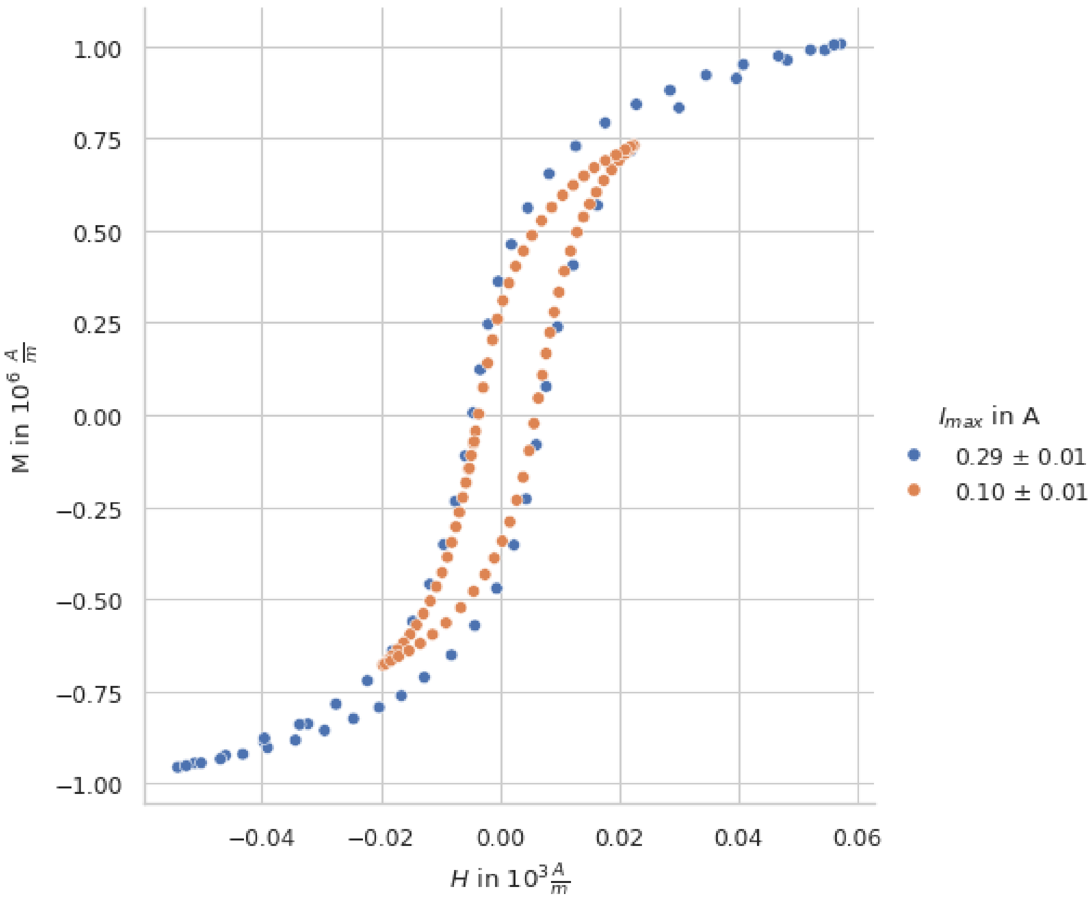
[10]:
```
heizbar_a[H_column] = heizbar_a['H'].apply(H)
heizbar_b[H_column] = heizbar_b['H'].apply(H)
heizbar_c[H_column] = heizbar_c['H'].apply(H)
heizbar_d[H_column] = heizbar_d['H'].apply(H)

heizbar_a[M_column] = heizbar_a['M'].apply(M)
heizbar_b[M_column] = heizbar_b['M'].apply(M)
heizbar_c[M_column] = heizbar_c['M'].apply(M)
heizbar_d[M_column] = heizbar_d['M'].apply(M)
```

Alle Messungen in einem Plot

[11]:
```
heizbar_all = pd.concat([heizbar_a,heizbar_b,heizbar_c,heizbar_d])
plot(heizbar_all)
```



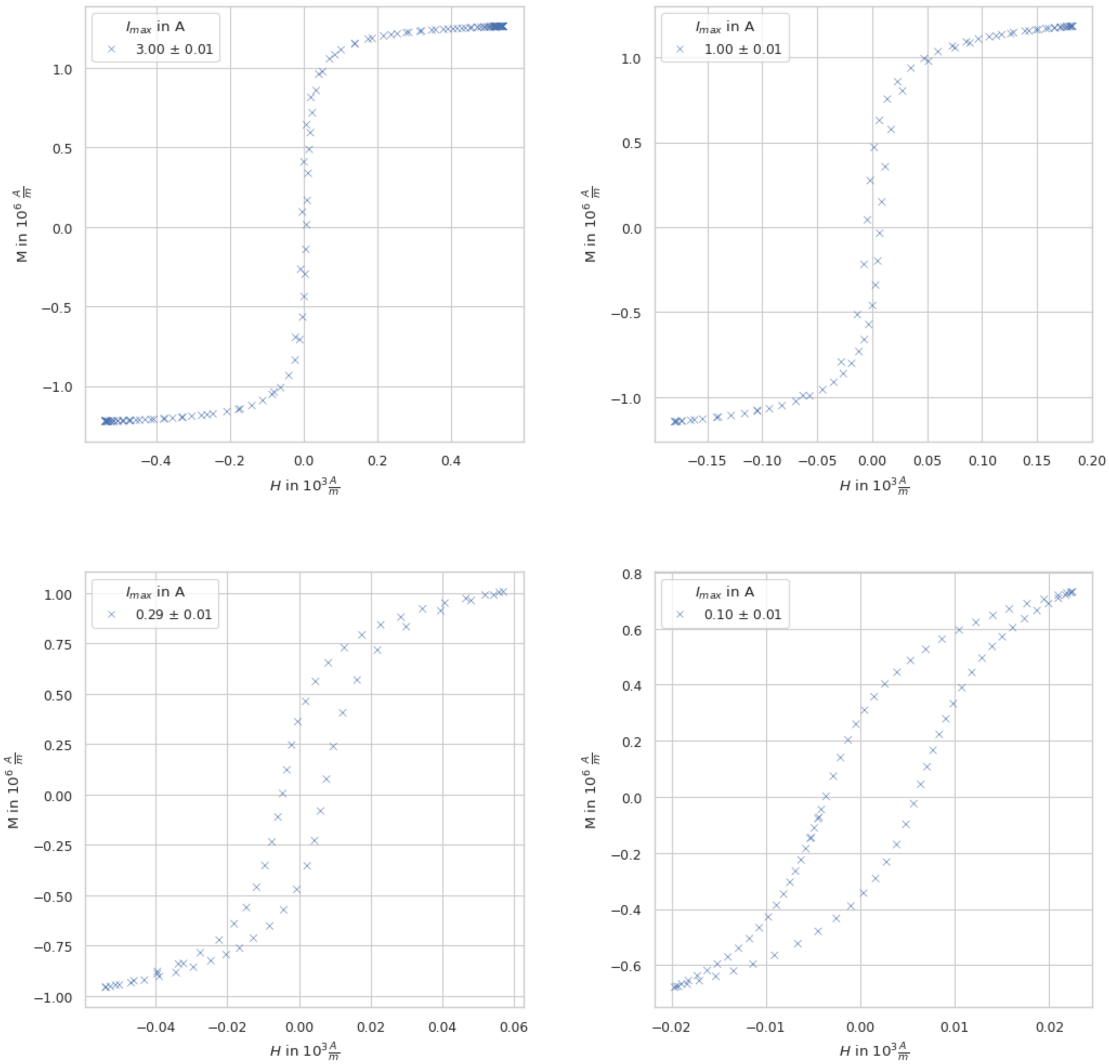
[12]:
```
plot(pd.concat([heizbar_c,heizbar_d]))
```



Alle Messungen in verschiedenen Plots

[13]:
```
fig = plt.figure(figsize=(12,12))
fig.subplots_adjust(hspace=0.3, wspace=0.3)

# 4 subplots jeweils 1/2 Breite
# https://matplotlib.org/stable/api/figure_api.html#matplotlib.figure.Figure.
↪add_subplot
ax = fig.add_subplot(2, 2, 1)
subplot(heizbar_a, axis=ax)

ax = fig.add_subplot(2, 2, 2)
subplot(heizbar_b, axis=ax)

ax = fig.add_subplot(2, 2, 3)
subplot(heizbar_c, axis=ax)

ax = fig.add_subplot(2, 2, 4)
subplot(heizbar_d, axis=ax)
```

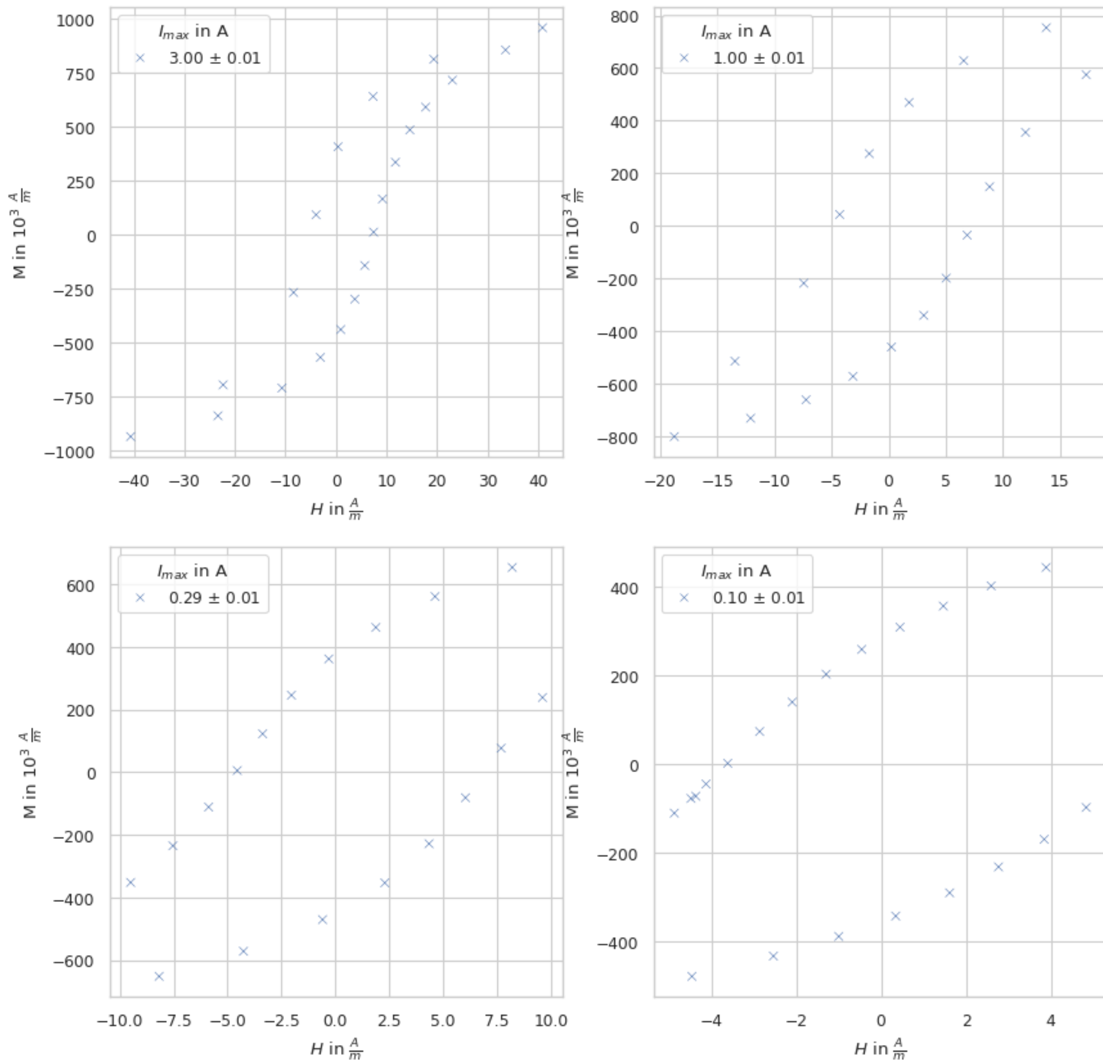
```python
fig.savefig('../../media/B2.4/3.3.1_single_measures.svg', bbox_inches='tight')

plt.show()
```



[33]:
```python
heizbar_a[H_column_detailed] = heizbar_a[H_column] * 1000
heizbar_b[H_column_detailed] = heizbar_b[H_column] * 1000
heizbar_c[H_column_detailed] = heizbar_c[H_column] * 1000
heizbar_d[H_column_detailed] = heizbar_d[H_column] * 1000

heizbar_a[M_column_detailed] = heizbar_a[M_column] * 1000
heizbar_b[M_column_detailed] = heizbar_b[M_column] * 1000
heizbar_c[M_column_detailed] = heizbar_c[M_column] * 1000
heizbar_d[M_column_detailed] = heizbar_d[M_column] * 1000
```

[35]:

```
fig = plt.figure(figsize=(10,10))
#fig.subplots_adjust(hspace=0.3, wspace=0.3)

# 4 subplots jeweils 1/2 Breite
# https://matplotlib.org/stable/api/figure_api.html#matplotlib.figure.Figure.
↪add_subplot
ax = fig.add_subplot(2, 2, 1)
subplot(heizbar_a[heizbar_a[H_column].abs() < 0.05], axis=ax,␣
↪x_column=H_column_detailed, y_column=M_column_detailed)

ax = fig.add_subplot(2, 2, 2)
subplot(heizbar_b[heizbar_b[H_column].abs() < 0.02], axis=ax,␣
↪x_column=H_column_detailed, y_column=M_column_detailed)

ax = fig.add_subplot(2, 2, 3)
subplot(heizbar_c[heizbar_c[H_column].abs() < 0.01], axis=ax,␣
↪x_column=H_column_detailed, y_column=M_column_detailed)

ax = fig.add_subplot(2, 2, 4)
subplot(heizbar_d[heizbar_d[H_column].abs() < 0.005], axis=ax,␣
↪x_column=H_column_detailed, y_column=M_column_detailed)

fig.savefig('../../media/B2.4/3.3.1_single_measures_detailed.svg',␣
↪bbox_inches='tight')

plt.show()
```




```
[87]: heizbar_a['Ringkern'] = 'ohne Spalt'
```

0.1.1 ermittle Remanenz

`threshold` muss so gewählt werden, dass maximal 3 Werte herausgefiltert werden. Ideal wären zwei, falls ein Wert oben und ein Wert unten ist.

```
[117]: df = heizbar_d
threshold = 0.7

df[df[H_column_detailed].abs() < threshold][M_column_detailed]
```

```
[117]: 33   -343.188088
73    309.343892
```

```
74    259.168560
Name: M in $10^3\ \frac{A}{m}$, dtype: float64
```

[103]:
```
m = df[df[H_column_detailed].abs() < threshold][M_column_detailed].abs().mean()
d = df[df[H_column_detailed].abs() < threshold][M_column_detailed].abs().std()
print(m.round(2), r'\pm', d.round(2))
```

```
303.9 \pm 42.27
```

0.1.2 ermittle H_K

`threshold` muss so gewählt werden, dass maximal 4 Werte herausgefiltert werden. Ideal wären zwei, falls ein Wert oben und ein Wert unten ist.

[140]:
```
df = heizbar_d
threshold = 50

df[df[M_column_detailed].abs() < threshold][[M_column_detailed,
 ↪H_column_detailed]]
```

[140]:

	M in $10^3\ \frac{A}{m}$	H in $\frac{A}{m}$
0	-44.867783	-4.128412
38	-24.091637	5.661485
39	44.802778	6.398923
78	1.973907	-3.617576

[141]:
```
m = df[df[M_column_detailed].abs() < threshold][H_column_detailed].abs().mean()
d = df[df[M_column_detailed].abs() < threshold][H_column_detailed].abs().std()
print(m.round(2), r'\pm', d.round(2))
```

```
4.95 \pm 1.3
```

0.1.3 $M_{\max}$

[164]:
```
df = heizbar_d
m = (df[M_column_detailed].max() + abs(df[M_column_detailed].min()))/2
d = (df[M_column_detailed].max() - abs(df[M_column_detailed].min()))/2
print(m.round(2), r'\pm', d.round(2))
```

```
705.29 \pm 26.18
```

0.2 3.3.2

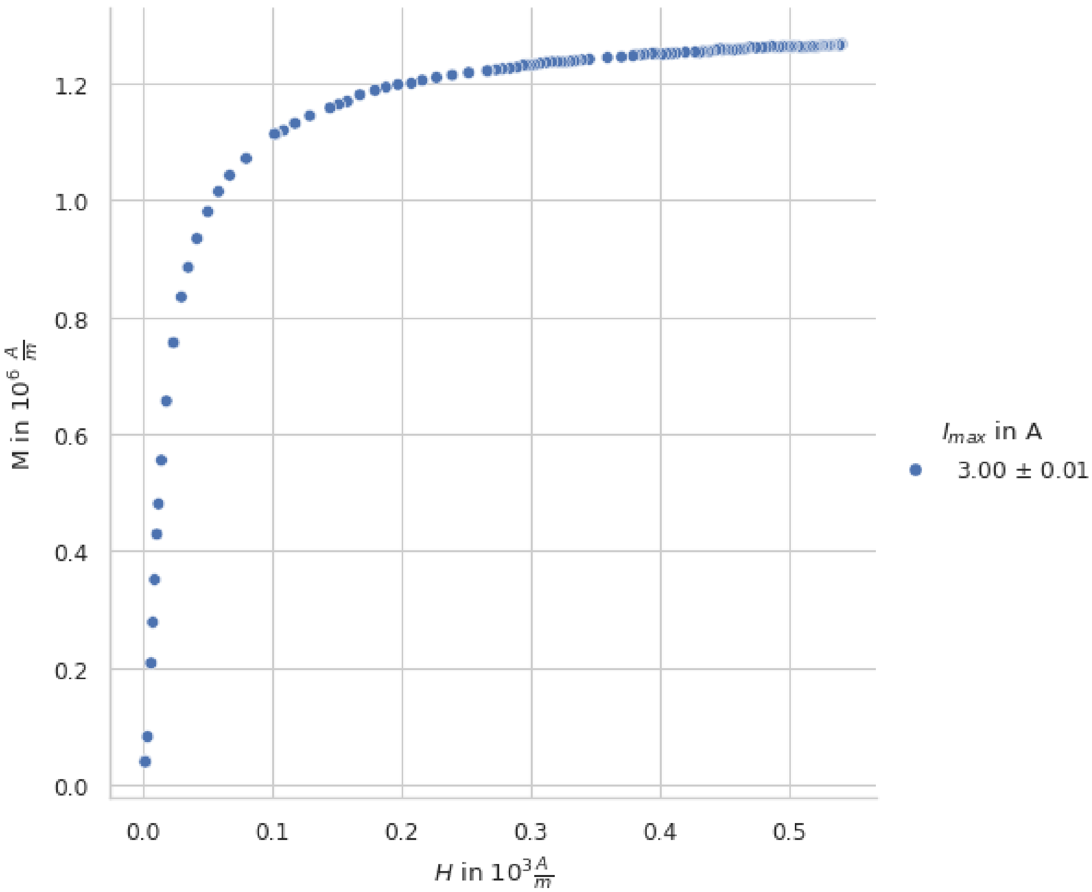
[17]:
```
komm_a = pd.read_csv('3.3.2.a.csv', sep='\t')
komm_b = pd.read_csv('3.3.2.b.csv', sep='\t')
```

[18]:
```
komm_a[H_column] = komm_a['H'].apply(H)
komm_b[H_column] = komm_b['H'].apply(H)
```

```
komm_a[M_column] = komm_a['M'].apply(M)
komm_b[M_column] = komm_b['M'].apply(M)
```

[19]:
```
komm_a[I_column] = r'3.00 $\pm$ 0.01'
komm_b[I_column] = r'0.10 $\pm$ 0.01'
```

[20]:
```
plot(komm_a, filename='../../media/B2.4/3.3.2_rough.svg')
```

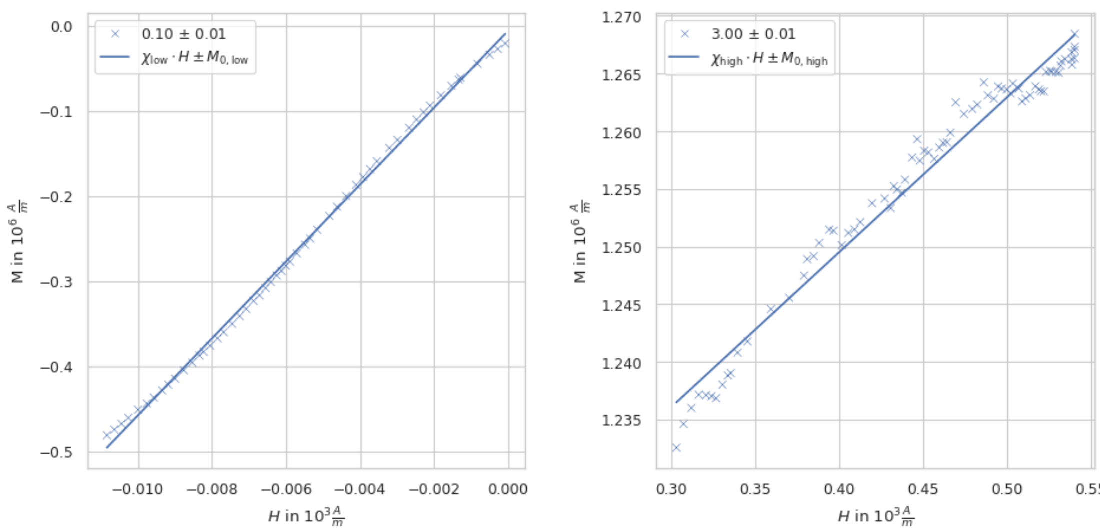


[21]:
```
def regression(df, ax, index):
    slope, intercept, _, slope_err, intercept_err = linregress(df[H_column],␣
 ↪df[M_column])
    x_vals = [df[H_column].min(), df[H_column].max()]
    y_vals = [ slope * x + intercept for x in x_vals ]
    subplot(df, axis=ax)

    label = r"$\chi_\mathrm{" + index + r"}\cdot H \pm " + r"M_\mathrm{0," +␣
 ↪index + '}$'
    sns.lineplot(x=x_vals, y=y_vals, ax=ax, label=label)
```

```
    ax.legend()

    print(f'slope {index}:', slope, r'\pm', slope_err)
    print(f'intercept {index}:', intercept, r'\pm', intercept_err)
```

[22]:
```
fig = plt.figure(figsize=(11,5))
fig.subplots_adjust(hspace=0.3, wspace=0.3)

ax = fig.add_subplot(1, 2, 1)
regression(komm_b[(komm_b[H_column] > -0.011) & (komm_b[H_column] < 0)], ax=ax,␣
 ↪index='low')

ax = fig.add_subplot(1, 2, 2)
regression(komm_a[komm_a[H_column] > 0.3], ax=ax, index='high')

fig.savefig('../../media/B2.4/3.3.2_regressions.svg', bbox_inches='tight')
```

```
slope low: 45.24608556109162 \pm 2.4987901598319533e-70
intercept low: -0.005873737273931756 \pm 0.2858802969771181
slope high: 0.13435596888357718 \pm 3.680030287083996e-58
intercept high: 1.1957831979185296 \pm 0.00274145641104781
```

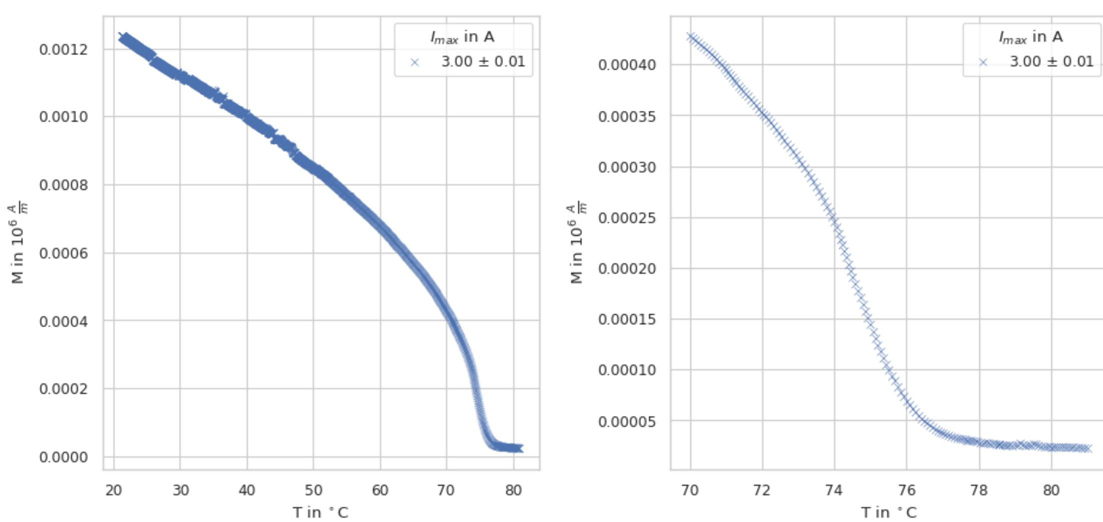


0.3 3.3.3

[23]:
```
data = pd.read_csv('3.3.3.csv', sep='\t')
data[I_column] = r'3.00 $\pm$ 0.01'
T_column = r'T in $^\circ$C'
data[T_column] = data['T']
data[M_column] = data['M'].apply(M)
```

```
data[M_column] /= 1e3
```

[24]:
```
fig = plt.figure(figsize=(11,5))
fig.subplots_adjust(hspace=0.3, wspace=0.3)

ax = fig.add_subplot(1, 2, 1)
sns.scatterplot(
    data=data,
    x=T_column,
    y=M_column,
    hue=I_column,
    marker='x',
    legend='full',
    ax=ax
)

ax = fig.add_subplot(1, 2, 2)
sns.scatterplot(
    data=data[data[T_column] > 70],
    x=T_column,
    y=M_column,
    hue=I_column,
    marker='x',
    legend='full',
    ax=ax
)

fig.savefig('../../media/B2.4/3.3.2_regressions.svg', bbox_inches='tight')
```



0.4 3.3.3

Messungsdetails: * 3.4.1: 0.94A * 3.4.2: 3.0A, 1mm * 3.4.3: 2.12A, 0.5mm * 3.4.4: 1.27A, 0.2mm * 3.4.5: 1.0A, 0.125mm * 3.4.6: 0.79A, 0.075mm * 3.4.7: 0.50A, 0.0mm

[25]:
```
spalt_a = pd.read_csv('3.4.1.csv', sep='\t')
spalt_b = pd.read_csv('3.4.2.csv', sep='\t')
spalt_c = pd.read_csv('3.4.3.csv', sep='\t')
spalt_d = pd.read_csv('3.4.4.csv', sep='\t')
spalt_e = pd.read_csv('3.4.5.csv', sep='\t')
spalt_f = pd.read_csv('3.4.6.csv', sep='\t')
spalt_g = pd.read_csv('3.4.7.csv', sep='\t')
```

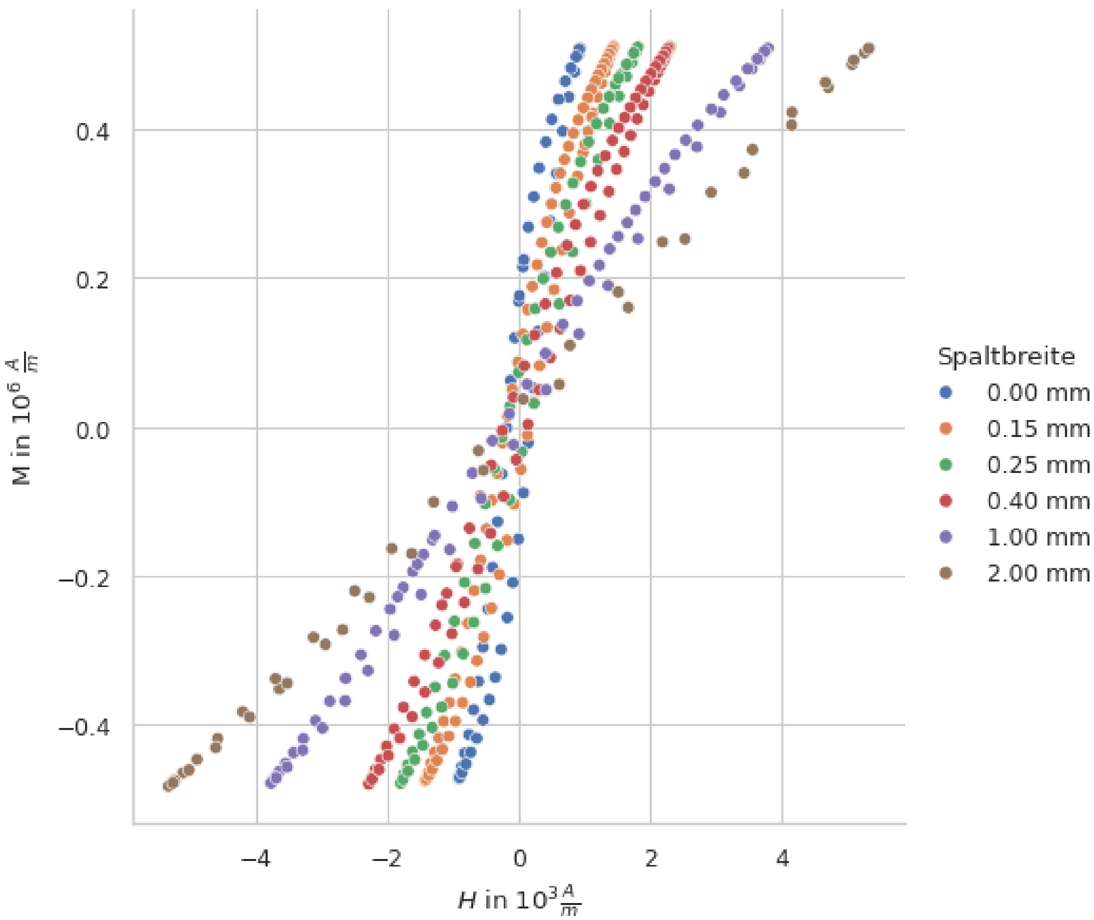
Fixme: Die Länge des Spalts muss eingerechnet werden.

[26]:
```
def H_spalt(U):
    U_max = spalt_a.H.max()
    n_p=54
    r=1.5/100 # m
    return n_p/(2 * math.pi * r) * (3.0/U_max) * U / 1e3
```

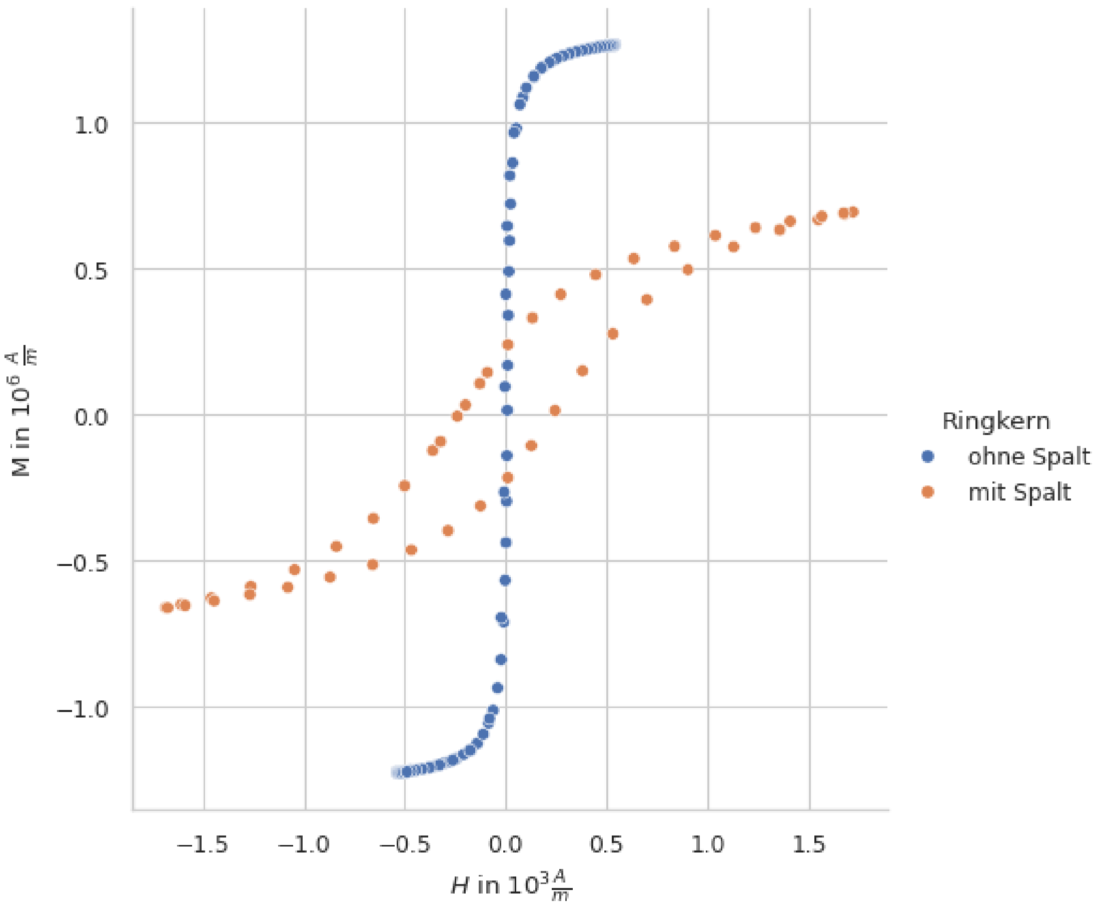
[27]:
```
spalt_a[H_column] = spalt_a['H'].apply(H_spalt)
spalt_b[H_column] = spalt_b['H'].apply(H_spalt)
spalt_c[H_column] = spalt_c['H'].apply(H_spalt)
spalt_d[H_column] = spalt_d['H'].apply(H_spalt)
spalt_e[H_column] = spalt_e['H'].apply(H_spalt)
spalt_f[H_column] = spalt_f['H'].apply(H_spalt)
spalt_g[H_column] = spalt_g['H'].apply(H_spalt)

spalt_a[M_column] = spalt_a['M'].apply(M)
spalt_b[M_column] = spalt_b['M'].apply(M)
spalt_c[M_column] = spalt_c['M'].apply(M)
spalt_d[M_column] = spalt_d['M'].apply(M)
spalt_e[M_column] = spalt_e['M'].apply(M)
spalt_f[M_column] = spalt_f['M'].apply(M)
spalt_g[M_column] = spalt_g['M'].apply(M)
```

[28]:
```
spalt_a['Ringkern'] = 'mit Spalt'

S_column = 'Spaltbreite'
spalt_b[S_column] = r'2.00 mm'
spalt_c[S_column] = r'1.00 mm'
spalt_d[S_column] = r'0.40 mm'
spalt_e[S_column] = r'0.25 mm'
spalt_f[S_column] = r'0.15 mm'
spalt_g[S_column] = r'0.00 mm'
```

[29]:
```
spalt_all = pd.concat([spalt_g,spalt_f,spalt_e,spalt_d,spalt_c,spalt_b])
plot(spalt_all, hue_column=S_column, filename='../../media/B2.4/3.3.3_overview.
 ↪svg')
```



[30]:
```
plot(pd.concat([heizbar_a, spalt_a]), hue_column='Ringkern', filename='../../
 ↪media/B2.4/3.3.3_comparison.svg')
```



1.0
0.5
0.0
−0.5
−1.0
M in $10^6\,\frac{A}{m}$
−1.5
−1.0
−0.5
0.0
0.5
1.0
1.5
H in $10^3\frac{A}{m}$
Ringkern
ohne Spalt
mit Spalt